

Quarterly Report FY09Q3

Date: December 10, 2009

Project Name: PHENIX Forward Muon Trigger Upgrade

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Introduction

This report has been prepared as input for the quarterly review of the PHENIX Muon Trigger Upgrade Project on December 10, 2009. We summarize the progress made since the last quarterly report on May 26, 2009 and present our plans for progress in the next few months. Recently an important milestone in the project was reached with the complete installation of the RPC3 detector in the PHENIX North area. In section A we discuss progress made and plans for the construction and installation of the rest of the RPC detectors, the RPC electronics and software and simulations. In section B we present the status of the project budget and in section C we discuss the project schedule.

A. Status Reports and Plans

1. RPC Design, Construction and Integration

a. RPC Gaps, Design, Production and Delivery (Sung Park, Korea University)

Since the May report, KODEL continued its production of RPC 3C including 42 gaps of the lower component and 41 gaps of the upper component of RPC 3C which passed the quality assurance check. On June 11th, a total of 83 gaps for RPC 3C were shipped to BNL. Thus production of about 250 gas gaps needed for RPC 3A, 3B and 3C were completed.

On July 2nd, the bakelite for RPC 1 arrived at KODEL. RPC 1 has 4 types: S1A1, S1A2, N1A1 and N1A2. It took KODEL two months to produce these 4 different types of RPC 1 and the gas gaps were tested extensively for an additional month. On September 30th, 96 RPC 1 gas gaps amounting to 8 sets of each type of RPC 1 were shipped to BNL. This concluded the production of RPC gas gaps needed for the muon trigger upgrade.

b. RPC Boxes and Signal Plane Production (Xiaomei Li, CIAE and Matthias Grosse Perdekamp, UIUC)

The detector boxes and signal planes for the north and south RPC-3 detector stations were delivered to the RPC factory in the previous quarter. The production of the RPC-1 detector boxes and signal planes will start in February 2010 after completion of the ongoing tests with full size RPC-1 prototypes.

In the quarter reported we conducted some market investigation about the materials we are using, hoping to find more information about the quality and price of the materials. The aluminum and copper sheets we are using are of large size, which makes them especially hard to find. Especially when we only order a small amount, few companies

are willing to manufacture them for us. We have further engaged with the company which made the boxes and signal planes for RPC-3. Because it is not a business of significant volume to make the type of boxes and signal planes we need, they intended to discontinue and remove the tooling needed for the production of RPC detector boxes and signal planes. After further negotiation with them, they agreed to maintain the equipment and facilities that were used to make RPC detector boxes and signal planes. To find the raw material (aluminum and copper plane) is another issue that we have to face. This company agrees to keep an eye on the source of the raw material constantly so that they may be able to start purchasing the raw materials and making the boxes and signal plane in a relatively short time once we place new orders with them in the future.

In an independent effort, the group at CIAE has started an R&D project to develop position-sensitive signal planes. Currently this project is still in the design stage. The goal of the project is to further improve the position resolution of RPC detectors.

c. Preproduction of RPC Parts **(Rusty Towell, Abilene Christian, Brett Fadem, Muhlenberg)**

To assemble a RPC module requires many parts. The large main parts (gas gaps, readout strips and module boxes) are produced overseas and shipped to BNL. Many additional smaller but crucial components are also required. Collaborators from Abilene Christian University, Muhlenberg College and Morgan State University are producing most of these parts. These parts include the wires and transition cards that connect the readout strips to the front end electronics, the copper foils that surround the active parts of the detector, the high voltage cables that supply the HV to the gas gaps, and the insulating Mylar sheets.

During the late spring these parts were produced in Texas (Abilene Christian University) and Pennsylvania (Muhlenberg College) for the initial RPC3N modules that have recently been installed in PHENIX. During the summer a large team worked at BNL (see list below) and continued to produce and test all of these parts for the RPC3N modules. Additionally as time allowed, some of the parts for RPC3S were also completed. The parts completed were the HV cables and copper foils.

Work on the transition cards and Mylar foils has continued during the fall at ACU, Muhlenberg and Morgan State. These will be completed, tested, and shipped to BNL for use in the assembly of RPC3S modules.

SUMMER 2009 RPC Preproduction Parts Team Under the supervision of Prof. Brett Fadem and Prof. Rusty Towell

Abilene Christian University: Keller Andrews
Kyle Gainey
Ryan Wright

Doug Coley
Dillon Thomas

Morgan State University: Langston Parks

Ethan Allen

Kirk Drummond

Muhlenberg College:

David Broxmeyer
Tally Sodre

Caitlin Harper

d. RPC Half-Octant Structure Production (Matthias Grosse Perdekamp, UIUC)

The aluminum components for the RPC-3 half octant support frames, both for RPC-3 north and south were machined at Hi-Tech-Mfg. in Schiller Park, IL. Hi-Tech-Mfg. won a competitive request for bids to 16 shops in Illinois, Indiana, Ohio, New Mexico, Iowa and China. The bid from Hi-Tech-Mfg. was \$90484.0 for all 32 half octants, south and north, compared to \$10900.0 from CIAE in Beijing.

Hi-Tech-Mfg. delivered all RPC-3 half octant parts to Urbana on May-12-2009. A team of 3 UIUC graduate students (Martin Leitgab, Cameron McKinney and Scott Wolin), 2 UIUC undergraduate students (Alex Burnap and George Deinlein) and 2 visiting REU summer students (Justine Ide from Muhlenberg College and Zarah Ahmad from Southeast Missouri State University) pre-assembled all half octant support structures in the high bay area of the NPL. A complete set of detector boxes was inserted into the half octant structures to detect possible tolerance issues. For each detector station, RPC-3 north and RPC-3 south, the complete set of 16 half octants was assembled into a full detector wheel and carefully surveyed. From this work it was found necessary to re-machine the internal support brackets. This work was carried out locally by NPL technician John Blackburn. Assembly, survey and re-machining of the RPC-3 north half octants were completed on June 15th and delivered to the RPC factory at BNL on June 19th.

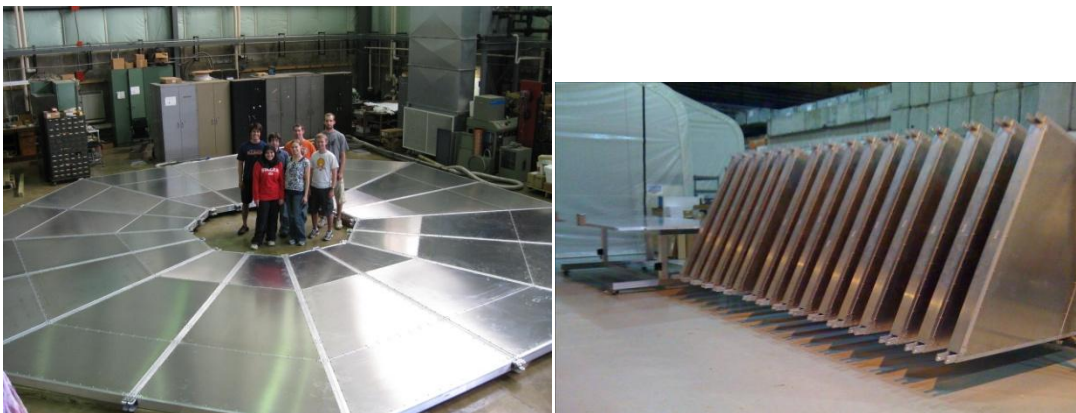


Figure 1. Left: Fully assembled and surveyed RPC-3 north detector wheel at NPL. Right: RPC-3 north half octants after delivery in the half octant test rack in the RPC factory at BNL.

Assembly, survey and re-machining of the RPC-3 south half octants was completed on September 14th. The south half octants are presently stored at NPL and will be shipped to BNL in January 2010.

e. RPC Half-Octant Assembly and QA (IhnJea Choi, UIUC)

16 pre-assembled half-octant frames were delivered at the RPC factory after a half-octant storage rack was installed. This rack we called the bicycle rack was built for the half-octant burn-in and storage. Half-octant assembly was started on 9th Aug. in the middle of the RPC module production. 3 shift crews from the RPC group, 3 graduate students from Korea and 2 Post Doc. worked on this assembly and completed all 16 half octants as of 23th Oct. We used QA passed RPC modules which had low dark current (same criteria as incoming RPC gap Q&A) and were below the noise rate limit ($< 10 \text{ Hz/cm}^2$), and passed the gas leak check, with no dead signal channel.

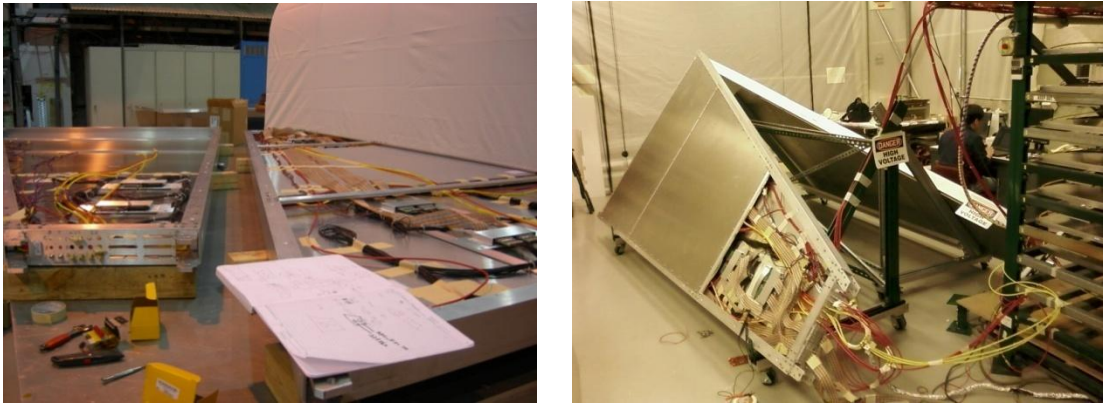


Figure 2 Picture of Half-Octant assembly and QA test

A movable half octant assembly table was used for the half-octant assembly. When one was completed, it was moved inside the RPC module assembly tent for QA tests by using a movable tilting table and crane. Figure 2 shows the half-octant assembly and QA test. Since the RPC FEE board could pick up noise from signal and LV cables inside the octant, we have done cable routing again for reducing the noise rate. Figure 3(a) shows noise rates of all channels after completing assembly of 16 half-octants. Only a few channels are higher than the noise rate limit (10 Hz/cm^2)

Dark currents were also monitored again. Figure 3(b) shows the results of complete RPC module dark currents at the end of RPC module QA in the cosmic ray test stand and all currents were below their limits. Also for half octant burn-in test the dark currents from half octants did not exceed the limits. We also checked that all service lines (which were L.V & H.V cables, signal ribbon cables, and gas tubes) are connected well and are connected to the right place on the half-octant patch panel.

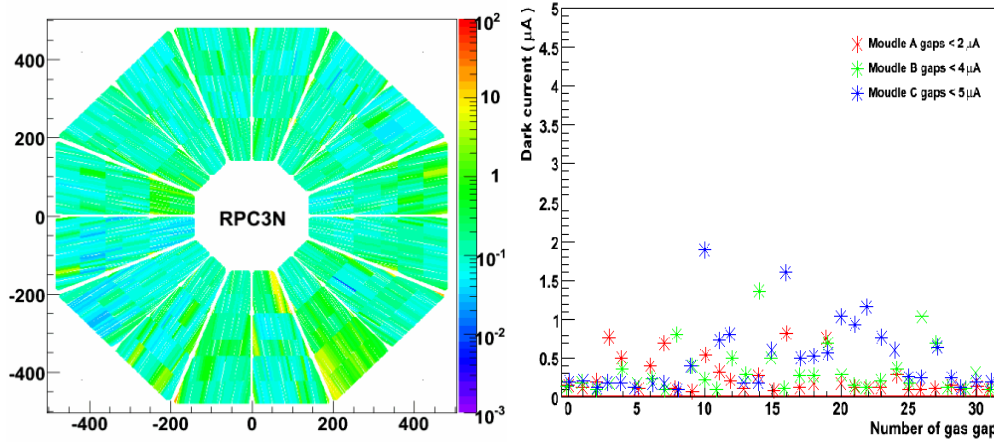


Figure3 (a) Noise rates of all channels.

Figure 3 (b) Dark currents of all gas gaps.

Half-octants had to be stored in the bicycle rack at least two weeks for their burn-in before these were delivered to the PHENIX tunnel. Figure 4 shows the bicycle rack for half-octant burn-in. During the burn-in period, the currents were monitored and recorded.



Figure 4: A bicycle rack for half-octant burn-in.

Additional tests of gas leakage, FEE boards, and HV cables were performed after all half-octants were installed in the PHENIX tunnel.

We will install all service lines to connect between RPC3 North and their racks in the next month. Assembly of the RPC3 south half-octants will start in the middle of RPC3 module production.

f. RPC Half-Octant Installation (Don Lynch, BNL)

The installation of the RPC3 North detector subsystem was planned to take place during the 2009 PHENIX summer shutdown. Plans developed prior to the start of the shutdown included several major elements occurring in parallel or series as appropriate and necessary to accomplish the overall goal of installation of the full station 3 north. These are as follows:

1. Design, fabrication, assembly, test and commissioning of RPC factory support equipment:

- Tilting transport Table
- Burn-in Test Stand
- Humidified storage racks
- Angled transport cart (4 in total)
- Dark Current Test Stand

These items were planned to be completed by July, before they were to be first needed. They were actually fully completed by the end of September, but we worked around the delays by prioritizing which equipment was completed first and utilizing the equipment in partially completed condition.

2. Fabricate support and assembly components for RPC3 North installation:

- Translating support base components
- $\frac{1}{2}$ - octant interconnection blocks
- Pitch control rails and runner connectors
- Upper $\frac{1}{2}$ -octant support brackets
- Rotational pivot pins

These items were planned to be completed by July, before installation practice and actual installation began. They were actually completed by the end of September, but we worked around these delays by prioritizing delivery in accordance with chronological need for the components.

3. Design, Fabrication, assembly and procurement of lifting/installation equipment

- $\frac{1}{2}$ -octant lifting fixtures (2, one each for mid-octant and octant edge sides of $\frac{1}{2}$ -octant)
- Walk behind crane (utilized existing crane owned by CAD)
- Hydraulic piston, piston drive oil pump, mounting brackets and adapting fixtures
- Positioning and handling fixtures

These items were planned to be ready by July, before installation practice and actual installation began. They were actually completed by the end of July, but we discovered some deficiencies during simulation tests for rotating ½-octants 7 & 8 east & west which required re-evaluation and led to an alternate solution which was implemented by the end of September.

4. Equipment testing and commissioning, and installation technique simulations:

- Lifting fixture analyses, test and approval
- Base grout performance tests (application and flow characteristics)
- ½-octant handling simulation
- ½-octant installation simulation

These tasks were to be performed in July. Delays in some of the installation components and fixtures caused the simulations to be continued into August and early September.

5. Half-octant assembly, testing and preparation for installation:

- Initial assembly on assembly table
- Electronics and gas connection initial tests inside factory
- Burn-in tests
- Final assembly of installation components (interconnection blocks), mounting of appropriate lifting fixture, placement in angled transport cart

These tasks took longer than expected and the first ½-octants were not ready until late August. Once the initial item was completed and the details of assembly and testing had been debugged, subsequent items were produced in a timely and predictable fashion.

6. Installation site preparation:

- Temporarily re-locate north tunnel shielding, access catwalks, F-Cal wiring, and any other equipment which potentially would interfere with installation
- Disassemble vapor barrier and crystal palace
- Clear debris from gap 5
- Temporary and final re-routing of piping and wiring in gap 5
- Pre-grout preparation: sealing of cracks and damming openings for grout containment
- Survey markings for alignment and precision support structure attachment to gap 5 steel and adjacent surfaces

These tasks were planned to be completed by the end of July. They were completed on or nearly on-time.

7. Mechanical installation:

- Install base support structure

- Install pitch control and upper level support structure
- Install individual ½-octants
- Test individual ½-octants
- Final alignment and survey

Mechanical installation was planned to be commenced in early August and last until the end of September. Installation actually commenced in mid September and continued until mid November. During the installation, several not unexpected interferences were encountered. The high level of planning and pre-installation simulations assured that solutions to these problems were readily attainable and were ultimately achieved without any significant impact to the schedule. Currently, all tasks are completed except for part of the final survey.

8. Electrical and gas services and environmental control:

- Install 2 new racks
- Install new cable management system (cable trays)
- Install new rack components
- Re-store all temporarily moved wiring and piping to operational routing
- Build new thermal/vapor barrier
- Install thermal control (heater, thermostat, air distribution)

These tasks were planned to begin by mid October and continue until the end of November. These are currently in progress and expected to be essentially completed by the end of November. As factors other than the RPC3 North installation have caused the start of Run 10 to be delayed until December 5, there is some additional time to complete the remaining tasks. There are additional tasks which were not expected to be completed during the current shutdown which will be scheduled when time and access is available during Run 10 and during the 2010 shutdown.

9. Site restoration:

- Restore shielding, access catwalks, F-cal, etc. to pre-installation configuration

These tasks were scheduled to commence during November and be completed prior to Run 10 startup. They are currently in progress and expected to be completed on time.

10. Installation closeout:

- Review all tasks undertaken for North installation
- Determine areas of improvement
- Assign action items to address improvable items
- Establish plans and schedule for RPC3 South installation
- Implement plans and schedule

In the next few weeks PHENIX engineering, technicians, CAD liaison engineers, BNL tradespersons and RPC experts will meet to evaluate the success of the RPC3 North installation, discuss lessons learned and make suggestions for improvements to the equipment, tools, fixtures and techniques as used in the RPC3 North installation in the application of these items to the RPC3 South installation scheduled for the 2010 shutdown.

g. North Area Half Octant Testing (Ruizhe Yang, UIUC)

All sixteen half octants in RPC3 North were tested in October and November. Tests on each half octant followed immediately after its installation in order to identify issues as early as possible. However, no major problem has been found.

Three tests were performed on the half octants:

1. Gas leak check

In order to check for possible gas leaks in the gas gap, Freon was circulated for approximately 10 minutes. Pressure of 3 inches of water was applied with the input channel sealed, and then the return pressure was monitored for 30 minutes. This test was repeated for all six gas gaps inside each half octant. Two leak points were detected in one half octant: one was caused by using a less optimal gas connector at the early stage of RPC mass production and was fixed by using the new connector. The other leak resulted from a loose connection at the patch panel during the assembly and was fixed by simply tightening it. After fixing this half octant, no other gas gap was found to have a pressure drop above 2.5% in 30 minutes. The tests demonstrated that all half octants remain gas-tight after installation.

2. High voltage test

High voltage of 2000 V was applied to every gas gap, and the observed currents were all below 0.1 μA . This indicates that no major damage has occurred to the gas gaps during transportation and installation. High voltage was provided by a Bertan NIM module that can supply negative voltage up to 5000 V. Further testing at higher voltage is necessary to fully assess the condition of the gas gaps once Freon can be circulated for an extended period of time.

3. Data readout test and noise rate test

To verify that all signal cables remain correctly connected after the installation, front end electronics (FEE) boards are powered up and a readout chain has been set up to extract pulses from the RPC read out strips.

This setup is illustrated in Figure 5.1. It resembles the real setup that will be used in the future for triggering and data taking during future physics running at RHIC. Raw signals

are amplified and digitized by FEE boards on the half octant, then propagate through 10 meter long LVDS cables to TDC modules inside a customized crate (the “Nevis crate”), from where an XMIT module serializes data and push them through an optical fiber to the 1008 rack room. A data collection module (DCM) unpacks data from the other end of the fiber and writes them to an NFS disk. A clock master module is used to control communication between TDCs, FEE boards, granule timing module (GTM) and DCM. By interacting with the clock master, the threshold levels can be set on the FEE boards, and different trigger modes and data taking modes can be chosen.

Power supplies and part of the read out chain need to be as close as possible to the detectors. Therefore, a portable rack was used in the RHIC tunnel for this test. LV power for the FEE boards is supplied by a standalone AGILENT power supply at 6.0V. Each FEE board draws 0.4 A current on average which is comparable to the current observed previously during half octant assembly. The Nevis crate and clock master are powered by other standalone LV power supplies at 4.0 V, 5.0 V, 6.0 V. A photo of the portable rack is shown in Figure 5.2.

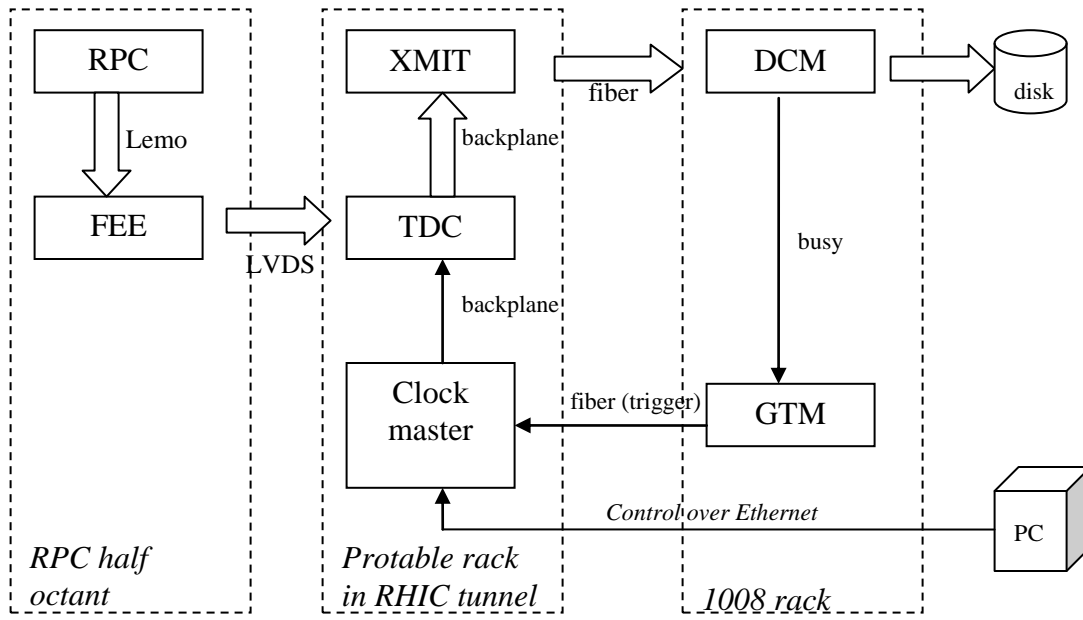


Figure 5.1 Block diagram for the read out chain used in half octant testing

Agilent for
FEE boards

TDC,XMIT in
Nevis crate

Bertan HV

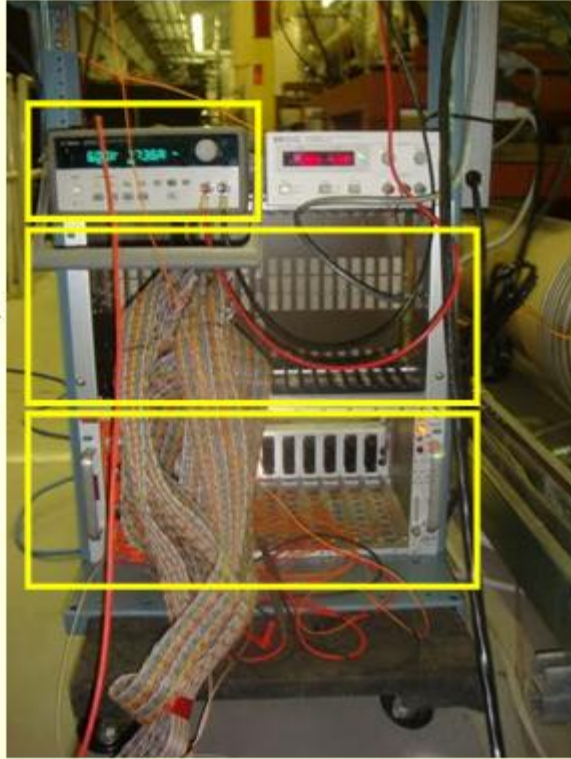


Figure 5.2 Photo of the portable rack used in half octant testing

Since no physics trigger is available before the next RHIC run starts, data taking is triggered by an internal clock (frequency at 10 MHz) from the GTM. Data taken in this mode gives an estimate of the noise rate in the RPCs. For every RPC module (48 in total for all half octants), 2000 events were taken with clock triggers. Table 1 lists, for each half octant, the number of channels with non-zero counts and average counts per event. Only very few channels from the total of 192 electronic channels in each half octant have observed non-zero counts. This shows that more than 95% of channels are completely quiet and this behavior is expected when no high voltage is applied during the test. The results also demonstrated that all installed FEE boards can communicate with the rest of the readout chain appropriately in a high speed, high volume read out mode.

Half octant	No. of channels	Counts per event
5W	2	0.57
6W	9	0.03
7W	8	0.50
8W	3	0.08
8E	2	0.02
7E	0	0.00
6E	6	0.22
5E	2	0.01

4E	2	0.00
3E	1	0.01
2E	4	0.23
1E	3	0.07
1W	9	0.66
2W	1	0.03
3W	1	0.00
4W	0	0.00

Table 1: Results from half octant noise rate testing

In summary, based on the test results presented above, the RPC modules installed in the northern RHIC tunnel have no gas leak, all gas gaps are in good condition, and the electronics is functioning correctly. Once a stable gas flow of Freon can be established, it is desirable to repeat the same tests with at a high voltage level closer to realistic operating conditions.

h. High Voltage Systems (IhnJea Choi, UIUC)

The RPC high voltage systems will be located at three places depending on the RPC detector station locations. One H.V system for both north and south RPC1 will be placed above the PHENIX central magnet and other H.V systems for RPC3 will be located inside the north and south tunnels of PHENIX. Figure 6 shows three locations of RPC high voltage systems. Two RPC3 north racks for data acquisition, low voltage power, and high voltage power supply were installed in the north tunnel on early Nov. 2009.

CAEN high voltage boards, power supplies, cables, and connectors will be used for this system. Due to the limited number of H.V channels we have, two high voltage channels will cover one RPC3 half-octant which has six inputs of high voltage for six gas gaps (Top and bottom gas gaps of module A, B, and C). We plan that one high voltage channel supplies the three top gas gaps and the other channel is for the other three gaps by splitting one channel into three channels.

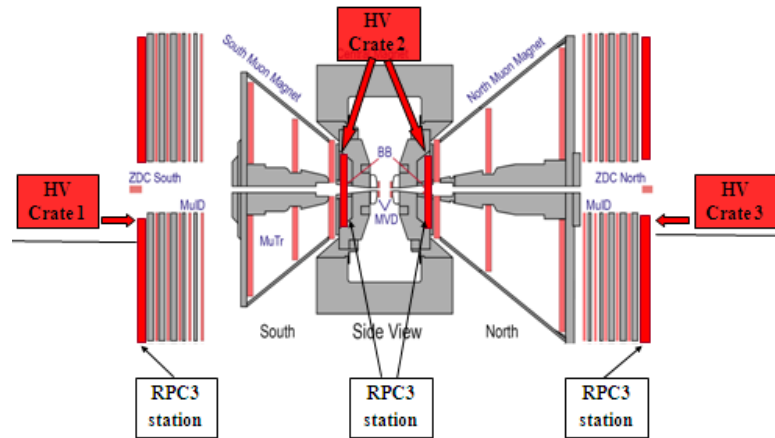


Figure 6: The three locations of the RPC high voltage systems

Thus, the HV distribution box was designed to split two HV channels into six channels. Since the last quarterly review on 26th May, We have made 16 boxes for RPC3 north. Figure 7 shows the 16 HV distribution boxes for RPC3 north



Figure 7 The 16 HV distribution boxes for RPC3 north

Similar HV distribution boxes which had one input split into six outputs were already tested in the bicycle rack when it was used for supplying HV for the half-octant burn-in.

These boxes will be installed in front of RPC3 north inside the PHENIX tunnel. HV cables for connection between the half octant and HV boards via the distribution box will be made in the next two months. HV power supplies and boards will be put inside the RPC rack in a month.

i. RPC Factory Progress and Status (Young Jin Kim, UIUC)

There has been significant progress in the RPC factory since the last quarterly review on May 26th. The following items are updates of various components of the RPC factory that occurred since the past quarterly review.

1) Gas system

Completeness of the gas mixing system upgrade was reported at the last quarterly review. As a result the gas flow capacity at the RPC factory is ~1 liter/min. and allows supplying gas simultaneously to the RPC gap dark current test stand (200 cc/min.), the RPC module cosmic ray test stand (200 cc/min.), and the RPC half octant burn-in station (600 cc/min.). The gas system was supplied to two test stands and the RPC half octant burn-in station without big problem but the Freon mass flow controller was replaced because it malfunctioned due to oil contamination from the Freon gas bottle around Aug. 29th.

Mini gas panels for individual half octants at the RPC half octant burn-in station are almost completed. 7 mixed gas panels, which can be switched to nitrogen gas panels, and 6 nitrogen gas panels are installed into the burn-in station. RPC half octant burn-in station and half octant transport table

The RPC half octant burn-in station was completed and consists of a half octant storage stand, mini gas panels, and H.V distribution boxes. The burn-in station is enclosed inside a plastic tent. Two air condition units control temperature. The RPC half octant storage stand was built of unistrut for a maximum capacity of 20 RPC half octants stored at the same time. Currently, 7 mixed gas mini gas panels and 6 nitrogen mini gas panels are installed and used. In addition to mini gas panels, 10 H.V distribution boxes, where one H.V distribution box has one H.V input to split 6 H.V channels serving H.V of a complete one half octant, are placed and used.

The half octant transport table has been completed and is functioning as planned: The transport table has been used for moving half octants from the half octant assembly table to the half octant storage stand, from the half octant storage stand to tilted half octant test stand, and vice versa. In order to lift the half octant from the half octant assembly table, half octant transport table or tilted half octant test stand, a 0.5 ton maximum capacity hoist has been installed with maximum capacity of 1 ton A- frame and they have been successfully used for handling half octants.

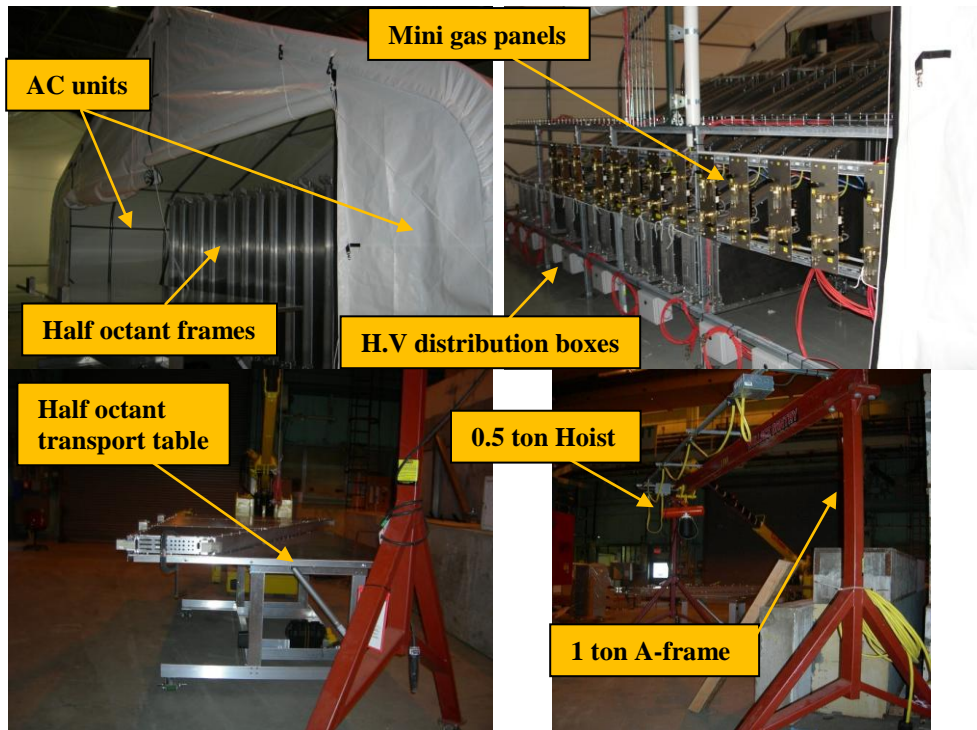


Figure 8: Half octant burn-in station, half octant transport table, A-frame with hoist.

2) RPC gap and detector module storage

The gas gap and detector module storage facility has been completed: 5 RPC gap and module storage shelves are enclosed with non-flammable welding curtains and equipped with two humidifiers. The entire RPC-3 and RPC-1 gaps for both north and south Muon Arms have been securely placed in the storage facility. In addition to this, a maximum of 15 RPC modules were stored in the storage facility during RPC-3 north half octant assembly.



Figure 9: RPC gap and module storages

4) RPC module part storage

Three large shelf structures have been placed next to the RPC half octant assembly area. All RPC-3 module parts (e. g. honeycomb panels, Al module

frames, readout strips) have been stored in the shelves. In addition to this, some of the shelves were used for temporary storage of large RPC modules during half octant assembly.



Figure 10: RPC modules stored in RPC module part storage

5) Mass production status

a) RPC gap incoming Q&A

The Q&A procedures include the RPC gap gas leakage test, the spacer pop-up test and dark current tests. A total of 112 RPC gaps for RPC-3 north were tested and four RPC gaps failed this Q&A. Three gaps failed at the stage of the spacer pop-up test and one gap was found to have a gas leak. The RPC gaps incoming Q&A for RPC-3 south is in progress.

The RPC gap incoming Q&A rate is 10 RPC gaps per week.

b) RPC-3 detector module assembly and Q&A

48 RPC-3 north detector modules (16 RPC modules for each different types of A, B, C) were assembled and passed their Q&A. Q&A of RPC detector modules includes gas leakage tests, dark current monitoring, noise rate measurement, performance tests with cosmic ray (e. g. efficiencies, cluster size with different FEE threshold values and H.V values).

The criteria for gas leakage and dark current monitoring are the same as RPC gap incoming Q&A and none of the modules failed these conditions. The results of noise rate measurement at H.V = 9.5 kV and FEE threshold = 160 mV shows that most of noise rates from individual signal readouts pass the specification requirement of $< 10 \text{ Hz/cm}^2$. The noise rates of 7 readout strips show higher values but they are less than 15 Hz/cm^2 and these readout strips are mostly the shortest strip at the octant boundary in the RPC modules.

The measurements of efficiency and cluster size of each RPC module with cosmic rays met specifications (efficiency $> 95\%$ and cluster size ≤ 2 strips at

RPC operating H.V values at or above 9.5 kV with FEE threshold values between 140 mV and 180 mV). The results show that most of the RPC modules have more than 95% efficiencies and less than 3 strip cluster size at a high voltage value above 9.5 kV and FEE threshold range from 120 mV to 180 mV. Some of RPC A and B modules show less efficiency. However, it was found that the lower efficiency was due to an acceptance effect in the cosmic ray test stand. This was demonstrated by swapping the location of detector module with low and high efficiencies in the cosmic ray test stand.

The average RPC module assembly rate is 1 module per day and Q&A rate is 5 modules per week.

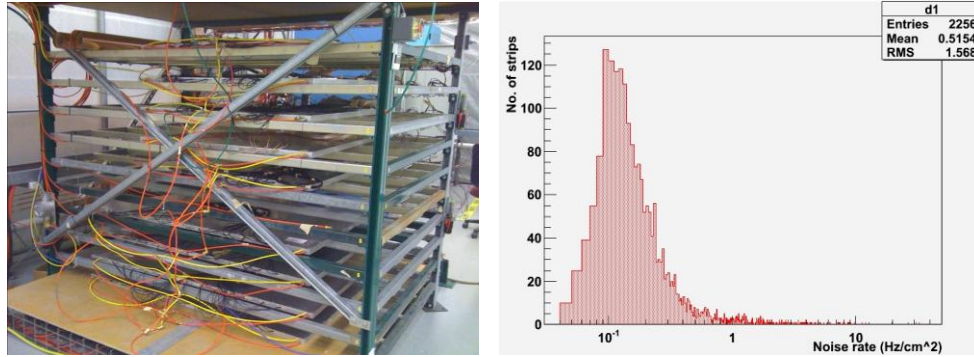


Figure 11: Cosmic ray test stand and the noise rates distribution for the readout strips of all 48 RPC-3 north detector modules

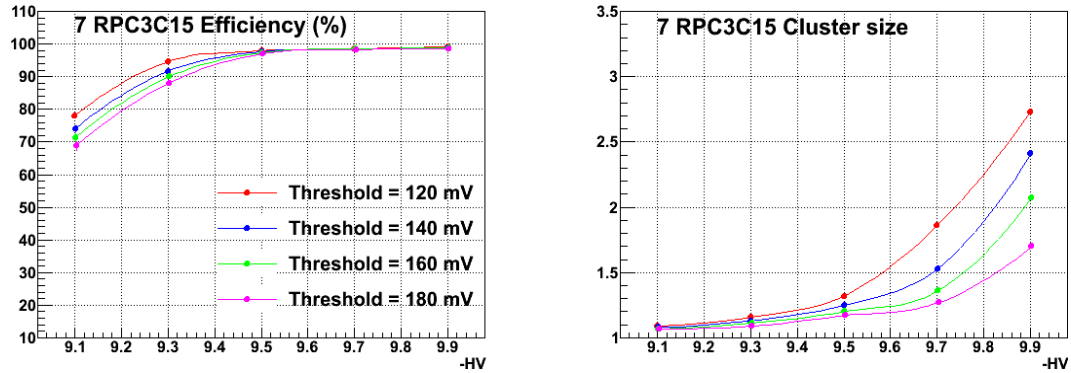


Figure 12: Example of the results of RPC module efficiency and cluster size measurement with cosmic ray

c) RPC-3 north half octant assembly and Q&A

Assembly of 16 RPC-3 north half octants was complete using a movable large size table. On the table, we are able to assemble two half octants in parallel. After completion of the half octant assembly, the two half octants are placed on unistrut tilt tables and moved into the RPC tent. In the tent, we monitored dark currents as

function of time and measured the noise rate at H.V = 9.5 kV and a discriminator threshold of 160 mV as the final Q&A.



Figure 13: Two RPC half octants on the movable large size assembly table.



Figure 14: Left: Unistrut tilt stands. 4 stands are available: 2 stands are used for RPC half octant tests inside the RPC tent and the other stands are used for transporting RPC half octants from the RPC factory to the north RHIC tunnel installation area. Right: RPC half octant Q&A inside the RPC tent

The result for the noise rates after half octant assembly is found to be better than the noise rates observed for individual RPC modules before assembly. This can be explained from the fact that the RPC detector modules and FEE boards are now located inside the half octant Faraday cage. Also the gas flows to modules was higher reducing noise from HV discharges.

After the noise rate test, the half octants are moved to the RPC half octant burn-in station for further dark current monitoring. Dark currents were monitored for 2 weeks and there was no monotonic increasing dark current observed.

The average RPC half octant assembly rate is 2 RPC half octants per week.

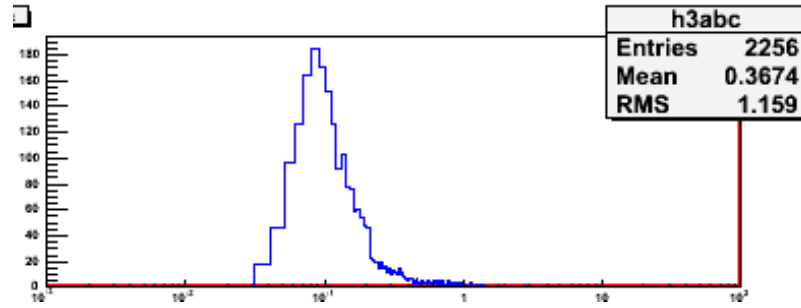


Figure 15: Distribution of noise rates for all readout strips of all 48 RPC-3 north modules after installation inside the half octant frames.

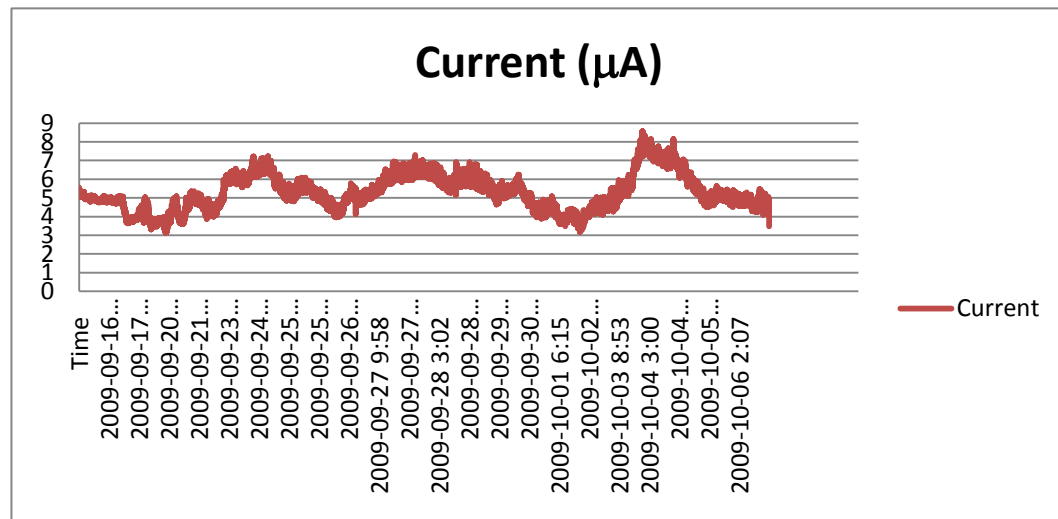


Figure 16: Example of dark current monitoring result vs time (half octant 1W).

d) RPC half octant installation and Q&A

The installation of all 16 RPC-3 north half octants in PHENIX experimental setup has been completed. These RPC half octants are located inside tunnel at the north side of PHENIX. After each RPC half octant installation finished, quick gas leakage test, H.V test, and readout chain test were carried out.

We plan to carry out detailed tests for gas leaks, of the H.V system and the readout chain including noise rate measurement during RHIC Run-10. For these tests, we need complete gas, H.V, L.V, readout electronics systems and their

distributions. Currently, the RPC group and PHENIX technicians are setting up these systems and preparing service lines.

e) Manpower at the RPC factory

Over summer time, 11 undergraduate students from Abilene Christian University (5), Muhlenberg College (3) and Morgan State University (3) worked for the production of RPC detector parts and 3 graduate students from Iowa State University (2), Banaras University in India (1) worked for RPC gap incoming Q&A and RPC module assembly.

During the entire RPC-3 north module and half octant production period, 2 UIUC postdocs, 4 UIUC graduate students and graduate students from Hanyang University (2) and Korea University (1) carried out all assembly and Q&A tasks.

In addition to the above factory staff, 24 RPC week long factory shifts were covered by various collaborators: UIUC (8), UCR (8), Korea University (4), Iowa State University (2), Georgia State University (1), and RBRC (1). The shift was responsible for the production of RPC half octant parts and the RPC half octant assembly.



Figure 17: The North RPC-3 detector station viewed from the RHIC tunnel after installation.

Following is the summary of the current activities in the RPC factory and the future schedule.

1) Current activities

All RPC-1 gaps from Korea arrived at BNL on October 20th. The RPC-1 gaps were stored in the gap storage facility.

RPC-3 north integration is under way.

Planning for RPC-3 north commissioning is in progress.

RPC-3 south gap incoming Q&A is under way (completed Q&A for 30 RPC-3 A gaps).

Testing RPC-1 prototype is in progress (noise rate and efficiency measurements).

2) Future Schedule at the RPC factory

Expect to complete RPC-3 south module assembly and Q&A by the end of February 2010.

Expect to complete RPC-3 south half octant assembly and Q&A by the end of April 2010.

Expect to complete entire RPC-1 module assembly and Q&A by the end of June 2010.

**j. RPC Prototype-D Installation and Operation
(Anselm Vossen, UIUC)**

As reported for the last quarterly review, two full size half octant prototypes were installed in the PHENIX north muon spectrometer. The first half octant, station 2, was installed just upstream of the muon identifier and the second half octant, station 3, downstream of the muon identifier. They were successfully integrated in the PHENIX DAQ and slow control. Their performance until the end of the run has been very successful.

Figure 18 shows a preliminary analysis of the timing distribution for the two innermost of the three modules in station 2 and 3. When fit with a Gaussian the width is about two TDC bins which have a width of 106ns/44. This by far exceeds the design requirements.

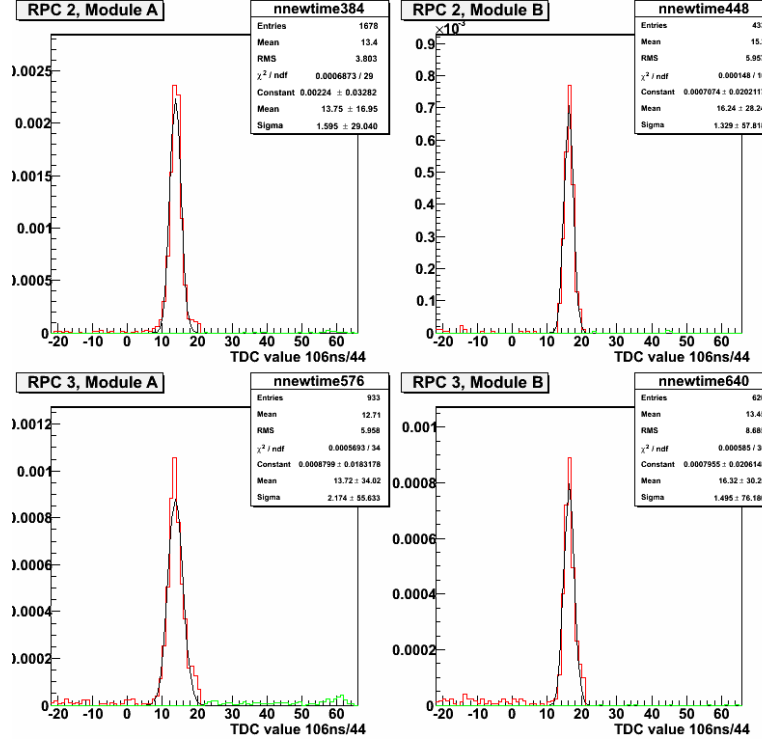


Figure 18: Timing distributions for the two innermost modules of prototype D at the location of RPC2 and 3. Module A (left side) is the innermost, module B (right) side in the middle.

For the module C, which is furthest away from the beam, the statistics in the produced data is not sufficient to extract the timing distribution. However, as all produced data is available that will be possible. Further studies to understand the timing structure are underway.

k. Results from Run-9 (Ralf Seidl, RBRC)

In Run 9 not only the RPC Prototype D was commissioned and tested, it was also the first run at 500 GeV. While several simulations were already performed in order to estimate the amount of background for muons originating from W decays, this will be the first time to compare it to data. Several tests need to be performed. The hadronic cross sections in the muon arms, which were so far estimated from different rapidities or NLO theory predictions, need to be evaluated and if necessary the amount of background needs to be scaled. As a second test also the actual spectrum of high transverse momentum muon candidates needs to be tested and compared to the previous simulations and those ongoing.

So far only the regular muon arm triggers are available, thus only a small fraction of the luminosity could be sampled. For muon candidates traversing up to the 4th gap in the iron

absorber plates this amounts to about 0.7 pb^{-1} . According to simulation in such a luminosity about 7 real W decay muons of each charge can be expected while thousands of low energetic hadrons decaying within the muon tracking system, mimicking a high momentum muon are dominating. The expected efficiency in reducing fake high pT track through tighter track candidate selections will be carefully studied using run 9 data.

Another test performed with the run 9 data uses an 30.5 cm (1.7 interaction lengths) octant of Pb absorber in front of the south muon arm to test a reduction of the fake high momentum muons. A clear reduction in yield has been visible for both, hadrons as well as high momentum muon candidates as can be seen in Fig. 19.

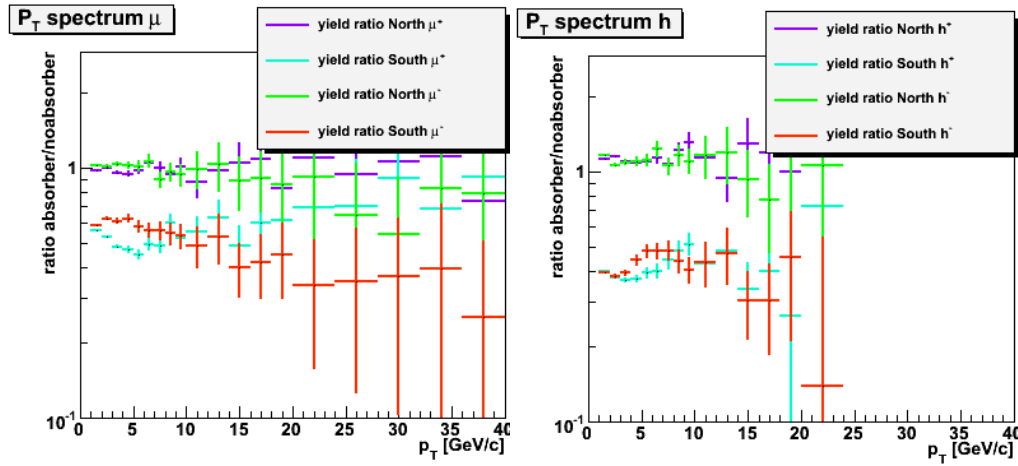


Figure.19 Acceptance corrected yield ratios for muon candidates (left) and hadrons (right) as a function of the transverse momentum between octants with and without absorber. Only the octants in the south contained an absorber, the north ratio therefore is expected to be unity.

1. RPC-1 Design (Ralf Seidl, RBRC)

Based on the Prototype RPC-1 detector results and measurements of the actual tolerances behind the PHENIX central magnet the design of the RPC-1 detector station has been slightly modified. The large density of readout channels especially in the split RPC gaps requires a larger space for soldering and to ensure good isolation for low noise levels. As a consequence the upper 6mm honeycomb panel will be replaced with a 2mm Al plate and foam spacers. This allows additional space where needed and the spacers will ensure a uniform pressure on the RPC gaps elsewhere. The cutouts for the readout will have two designs to potentially improve the readout cable routing and noise levels.

The second change determines the overall dimensions of the RPC1 modules. During the shutdown the actual space behind the central magnet was compared to the nominal space. While the current tolerances would still fit, it was decided to increase the amount of space between the modules and the magnet steel at the positions closest to the steel, namely at

the central area of the inner radius bar and at the octant edges on the outer radius. Also the routing of the HV cables has been modified based on the prototype experience.

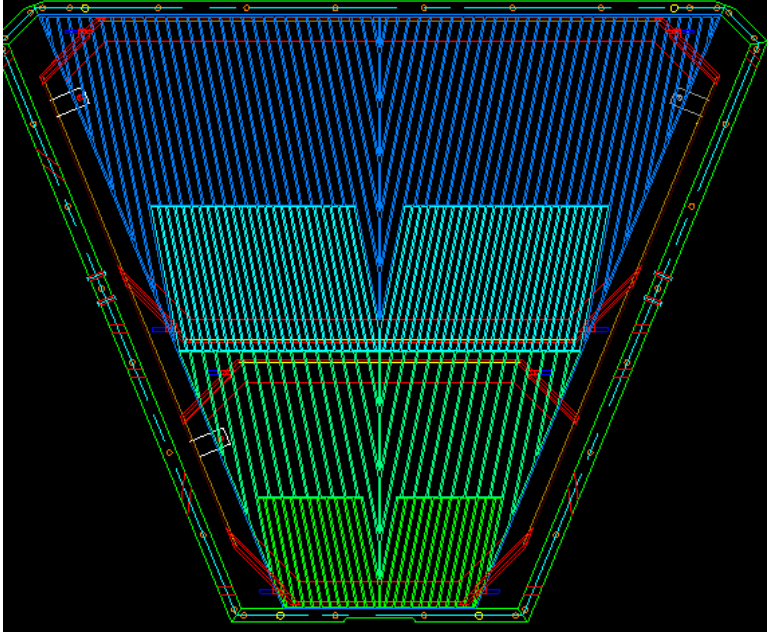


Figure 20: Modified RPC-1 module design.

The current design can be schematically seen in Figs. 20-21. None of these changes affects the actual RPC gaps which have arrived already at BNL. We will produce one further prototype but it is expected that the current design is almost final.



Figure 21: Al plate designs with different readout cable cutouts.

m. RPC-1 Prototyping (Anselm Vossen, UIUC)

In addition to RPC-3, RPC-1 is a critical part of the RPC part of the muon trigger upgrade. In contrast to RPC-3, of which the north side is already installed, the RPC-1 design was finished only in November after extensive prototyping. There are various challenges that are posed by the position of RPC-1 within the PHENIX detector that had to be overcome. Here I want to briefly describe how these influenced the design of the three prototypes that were built. Finally, first results of the last prototype will be discussed.

Architecture

Since RPC1 will be installed much closer to the interaction region in an area confined by the central magnet steel, the detector is much smaller and signal cables have to be brought out through the top cover and not the sides. Due to the small size, all rings are contained within one module. This dictates a ‘split-gap’ architecture which is discussed in detail in the conceptual design report (CDR). The initial design foresaw a two-plane architecture, with different positions for the split gaps in order to minimize the area where only single gap efficiency is available. RPC1-A had one split gap, whereas RPC1-B had two. The two split gaps would make at least one of the gaps so small, that production and assembly became problematic. Furthermore the ratio of active over dead area becomes unfavorable. Therefore it was decided to prototype one design with two split gaps and one where the two smaller gaps are merged, resulting also in the merging of the middle readout strip rings. These layouts are called RPC1-B1 and RPC1-B2 and are shown in Fig. 22.

For each of the three prototype designs, RPC-B1, B2 and A prototype parts were ordered and available at BNL. However RPC1-A did not pass the popped spacer test and the RPC1-B1 double split gap architecture did not seem to be a feasible option. So it was decided that for the final detector only one plane of RPC1-A type detector modules would be used and the RPC1-B2, which is similar to RPC1-A would be used for prototyping. With these gaps and the corresponding module, three prototypes were built and tested, incorporating experience gained from the previous ones. Figure 23 shows the different stages of the assembly of the first prototype.

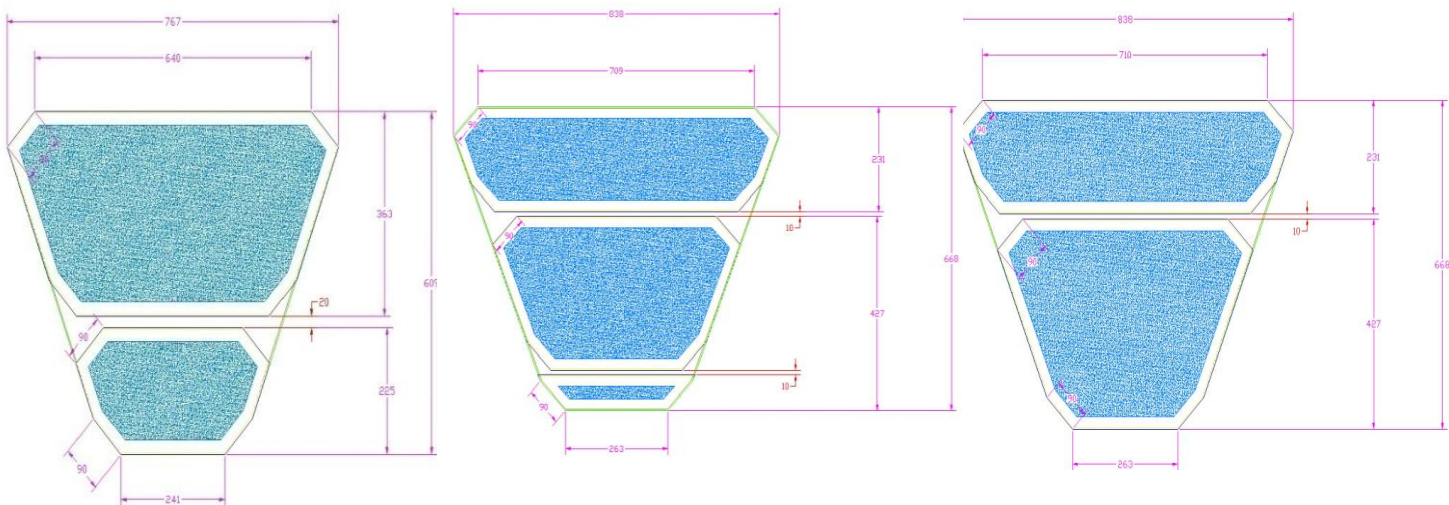


Figure 22: Gap Layouts. From left to right: RPC-1A, RPC-1B1, RPC-1B2. Not drawn to scale.

Prototypes:

The first prototype was assembled in a similar way to prototype D. First tests revealed very high noise rates, up to 100 Hz/cm^2 . After replacing the copper shielding for a second prototype, the noise rates dropped significantly. However they still varied widely over the detector. From 1 Hz/cm^2 to 100 Hz/cm^2 . To investigate the cause, tests were done with different grounding schemes for the signal cables and different layouts of the copper shielding. From these tests it was concluded that a grounding of the signal cables to the copper shielding instead of a grounding bus should be used. Furthermore, extending the copper shielding as far as possible over the regions where the signal cables are soldered to the readout strips is very important. The reason for this is that in these places the signal strips and readout cables are unshielded and exposed to RF noise.

This experience has been used in a third prototype. Here care was taken to minimize cutouts in the copper to bring out signal cables and these have been grounded directly to the copper shielding. First results have been encouraging. Noise levels are low, at around $(0.1 - 1) \text{ Hz/cm}^2$ and efficiencies of over 90% are reached. However these results are preliminary as tests have been done only on a very small part of the active area so far.

The experience with the third prototype led to design changes adopted for the final detector. The most significant ones are a change of the routing of the signal cables and a change of the upper and lower bars from a quadratic profile to an L-shaped one. The upper part of the L has a smaller width to provide more space inside the detector while the lower part keeps the gaps in place. The signal cables will be routed inside the detector and brought out through smaller cutouts. This will provide greater mechanical stability, as the cutouts are smaller, and better protection against RF noise, as their location is chosen such that the readout strips are not exposed anymore.

Another change in design is the use of a thinner cover and higher bars, in order to provide more space within the detector while keeping the outside dimensions the same. Since these design changes only pertain to the module box they can be tested without a change in the design of the gaps, which is not possible anymore.

Remaining challenges,

Using the experience gained from the various RPC1 prototypes, the design has been almost finalized. A last prototype will be built to test the new signal cable routing. From the current prototype we will extract efficiencies which could differ from RPC3 due to the smaller strip width. For the final detector a suitable layout of the readout boards together with appropriate shielding has to be developed. Due to the restricted space and the location of the detector close to the interaction region higher RF background is expected due to noise external to the detector and pickup from the more densely packed cables on the modules.



Figure 23: Different stages of the prototype. Top: RPC1-A gaps and module box. Bottom: detector during and after assembly.

2. RPC Electronics and Triggering

a. RPC Front End Electronics (Cheng-Yi Chi, Columbia) (Kenneth Barish, U. C. Riverside)

All the RPC discriminator modules have been tested at the University of Colorado and Columbia University. Except for a few modules, all the modules have been delivered to the RPC factory at BNL. All 167 TDC modules have been delivered from the assembly house in three batches. As was done for the discriminator modules testing, Columbia will sample test a few assembled modules from each delivered batch and the Colorado group will test the balance of the modules. The testing should be done by the end of the year. 20 fully tested TDC modules have been delivered to the RPC factory. Columbia also has 11 fully tested modules at this moment.

All the RPC crates have been assembled with custom backplanes. There are several modules, the clock master, clock fanout, and XMIT modules, that are necessary to support the readout electronics. Those modules are in the assembly and testing process. There are enough modules to readout the north RPC 3 detectors. We are installing the electronics in the beam tunnel.

The prototyping of the trigger module is on-going. The communication between the TDC module and the trigger module was verified before the TDC module fabrication. For RPC 3, we “OR” 2 TDC channels into 1 trigger bit. For the RPC 1 module, 1 trigger bit corresponds to 1 TDC channel. This is not a technical challenge, but it does create a slight schedule delay. The trigger module testing should be completed by the middle of January, 2010.

b. Status of MuTr FEE Upgrade (Itaru Nakagawa, RIKEN/RBRC)

New JSPS funded muon tracker trigger electronics (MuTRG-FEE) was installed in the PHENIX north muon tracker (MuTR) prior to Run 9. The new electronics has been operated successfully and detailed studies of the MuTRG-FEE electronics based on Run 9 data are underway. Further detail of offline analysis can be found in the following paragraph. The communication between the backend data collection and data merge (MuTRG-MRG) board and a LL1 trigger processor prototype tile has been also tested successfully. Production of the new MuTRG-FEE boards for the south muon spectrometer was completed by the early Summer 2009. They were fully installed as shown in Figure 24 throughout Summer to Fall of 2009 and to be commissioned in Run 10 using Au-Au beams.



Figure. 24: Installed new trigger electronics in South Muon tracker Station-1.

Shown in Figure 15 is the turn on curve of the trigger efficiency plotted as a function of track momentum evaluated using reconstructed tracks in the North MuTR. The trigger threshold is certainly pushed higher to around 8.5 GeV (parameter “p1” in Figure 15 fit) compared to the maximum threshold limit of about 2 GeV given by MuID. The plateau saturates around the efficiency of 0.9. This is the consequence of the product of the individual efficiencies in each station (about 0.98) and the vertex cut efficiency. Better efficiency can be achieved by relieving the operating conditions of the trigger electronics such as threshold, acceptance range of track sagitta, with or without strip clustering, AND or OR logic selection of MuTR redundant planes in each stations (MuTR chambers of

Station-1, 2, and 3 consisted of 3, 3, and 2 gaps, respectively. New trigger electronics were implemented to 3, 2, and 2 non-stereo planes of these stations, respectively for redundancy.) On the other hand, the higher efficiency would be the trade off between the rejection power. Shown in Figure 26 is the correlation between the trigger efficiency versus the total rejection power (BBC+MuID+MuTrig) evaluated at the BBC rate of 1.5MHz¹. Plotted data points are the performance of different operating conditions of new trigger electronics as described previously. The achieved efficiency of >0.9 is satisfactory at this BBC rate, which requires only the total rejection power of 750. Projected efficiency is about 0.8 at the rejection factor of 3000, which is the required factor at the projected luminosity of 1×10^{32} (expected BBC rate of about 6MHz) for Run11. Note this performance may be degraded as a function of the luminosity, particularly for rejection performance due to increasing accidental hits. Nevertheless, note these results are still preliminary and there is still plenty of room to improve the trigger performance. The following items are some ideas to be addressed in future studies to enhance the performance:

- More efficient MuID trigger algorithm
- Track Matching with MuID
- Timing cut by RPC
- Track matching with RPC
- Tighter background shields
- Quenching cross talks in MuTR chamber
- Etc.

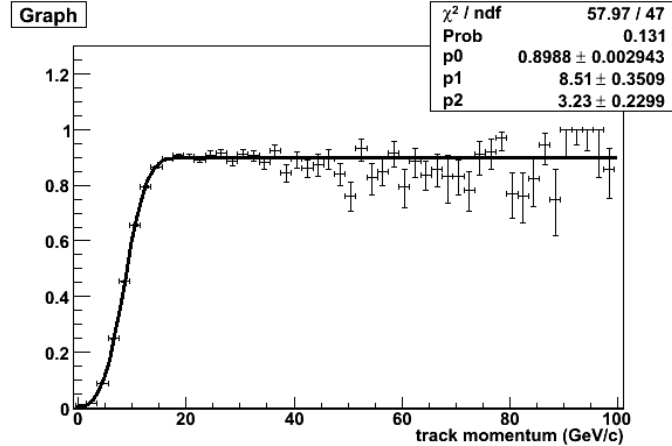


Figure 15: Turn on curve of the muon trigger as a function of track momentum evaluated from Run9 data in offline analysis.

¹ The BBC rate of 1.5MHz was the one of the highest luminosity run achieved in Run9.

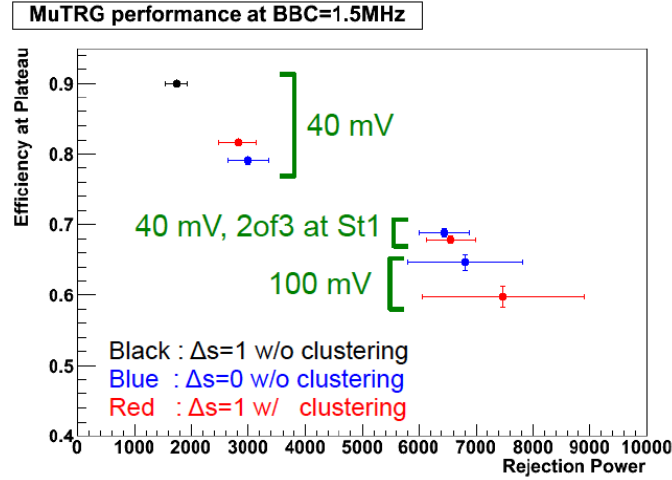


Figure 26: Correlation between the trigger efficiency vs. rejection power observed at BBC rate of 1.5MHz. 40mV and 100mV are threshold condition applied to the cathode signal at new trigger boards. $\Delta s=1$ and 0 represent the acceptance of sagitta range of strip ± 1 and ± 0 from the central strip of the trajectory.

c. Trigger Electronics (John Lajoie, Iowa State)

The electronics for the muon trigger upgrade Local Level-1 (LL1) system centers around a trigger “tile”, which is a small electronics board containing a Xilinx Virtex-5 FPGA and all the power supplies and required support logic for operation of the FPGA. Communication with the trigger tile is through up to 14 fast multi-gigabit serial links, capable of sending and receiving data at speeds up to 3.125 Gbps. In the muon trigger upgrade a single tile will handle the trigger algorithm for an octant of the full detector systems, receiving data from five optical fibers containing data from the RPC detectors, and four optical fibers containing data from the upgraded Muon Tracker Front End Electronics (MuTr FEE). These fibers will transmit data into the LL1 at 2.8 Gbps each.

In the past year the development of the LL1 trigger electronics has moved from the prototype stage through the production stage and into the deployment stage. During the recent RHIC run (January through June 2009) we succeeded in developing and testing a prototype trigger using an input from the PHENIX Muon Tracker detectors, which have been upgraded to include an LL1 data interface through a project funded by the JSPS.

A major milestone for RHIC Run-9 was the implementation and testing of a prototype trigger within the LL1 hardware. A channel and trigger mapping format was developed in conjunction with the KEK and Kyoto groups, and a basic trigger algorithm using only the MuTr detector elements was developed. Because ongoing trigger development could not interfere with physics data taking, the new muon trigger was not interfaced to the GL1 system at this time. Instead, a set of trigger counters were added to the trigger tile logic that could be started and stopped synchronously with the PHENIX DAQ. These trigger counters could be read out and compared with the results from an offline trigger emulator, which is a piece of software designed to reproduce the trigger decision from the PHENIX

data. For the base level algorithm, the counters and trigger emulator showed a strong correlation, indicating the trigger FPGA code was operating as expected. Because these trigger counters “see” every beam clock, and are not conditioned on the MuID LL1 as they will be in the final system, they did not measure a rejection that could be compared to the expected rejection of the full system. However, the comparison with the offline trigger emulator did demonstrate that a solid foundation has been laid for the completion of the muon trigger LL1 system in the coming year.

At the end of RHIC Run-9 we were developing a clustering algorithm for the MuTr strips. Because the passage of one track through the MuTr layer may fire more than one adjacent strip, this algorithm in the muon trigger will be essential to achieving the highest possible rejection power. Unfortunately, the run ended before we had completely tested this part of the trigger. We plan to continue this development in Run-10.

The production of the remaining three base boards was completed in October, 2008, the long delay being due to the availability of the FPGA tile to baseboard connector from the manufacturer. In preparation for Run-10 we have fully installed the LL1 system for the north muon arm at BNL and cabled in the necessary connections to the PHENIX Global Level-1 trigger system. The FPGA code required for a complete trigger for all sectors, including data transmission to GL1, has been completed and is currently under test at BNL. The complete setup will now allow the LL1 system to trigger the experiment, and allow a full event-by-event comparison between the LL1 and the offline trigger emulator. Such a detailed comparison is necessary to fully develop and commission the trigger, and we plan to use Run-10 Au+Au running to accomplish this for the MuTr portion of the trigger.

In the next six months, in addition to testing the MuTr portion of the MuTrig upgrade at BNL we will also conduct a data transmission chain test with the RPC electronics and begin the work to include the RPC information in the MuTrig LL1 system. Because we have agreed on the same data transmission protocol between the MuTr and RPC FEMs, we do not anticipate any major difficulties in integrating the RPC’s when the electronics become available.

In addition to integrating the RPC’s into the hardware, the RPC information will also be need to be integrated into the trigger algorithm FPGA code. This work will be done throughout the spring and early summer of 2010 and will be available in time for Run-11.

Personnel – LL1 Electronics

The LL1 electronics development is the responsibility of the ISU group. Major personnel and their responsibilities are listed below.

John Lajoie: Dr. Lajoie has overall management responsibility for the project, and has been heavily involved in the design of the Rev0 and Rev1 trigger tiles. He is currently

developing the FPGA programming to fully integrate the new muon trigger into the PHENIX Level-1 trigger system.

Roy McKay: Mr. McKay is a technician with the ISU nuclear and high-energy experimental physics groups. He has been responsible for the design of the Rev1 trigger tile, as well as various test fixtures, assembly, and repair/rework of existing boards.

Todd Kempel: Mr. Kempel is a graduate student with the ISU group and has worked extensively on the muon trigger upgrade project. As noted above, Mr. Kempel has been responsible for the clock testing and characterization for the trigger tile, as well as developing the early software for BERT testing and testing the trigger tile communication with the Muon Tracker MRG boards.

Andy Goers: Mr. Goers is an ISU undergraduate with our group and as worked on a variety of projects. He has been responsible for the BERT testing of the Rev1 trigger tiles and FPGA programming for multiple GTP testing, as well as FPGA programming for the auto-alignment code for the input fibers.

3. Software, Simulations and Backgrounds

a. Simulations (Ralf Seidl, RBRC)

In the past quarter the RPC geometry has been added to the PHENIX reconstruction software as well as to the detector simulation. First attempts at including the additional offline RPC hit information in the track reconstruction in the muon arms seems to be promising and it is expected that it will further reduce other backgrounds in the $W \rightarrow \mu$ analysis. It is expected that the inclusion will be finished in the next quarter.

In conjunction with the Run9 data analysis a new full detector simulation has been started in order to understand the backgrounds more thoroughly and confirm them in the data. For this purpose a full PYTHIA 6.4 simulation has been started using the tune A which reproduces most of the 200GeV cross sections measured at RHIC. No direct comparisons of this tune to 500GeV RHIC data can be performed, but some differences are possible. The events are generated separately for different sub-processes: light and diffractive physics, open charm, open bottom, onium production, direct photon processes, Drell Yan and Z boson processes, W boson processes as well as Z+jet and W+ jet processes. Those events are then processed by the PHENIX detector simulation (based on GEANT) and reconstructed by the Muon Arm reconstruction software.

At present the amount of produced statistics are already comparable to the run9 luminosity for the less abundant processes, while the light and diffractive processes need still more than two orders more of statistics (see Fig.27).

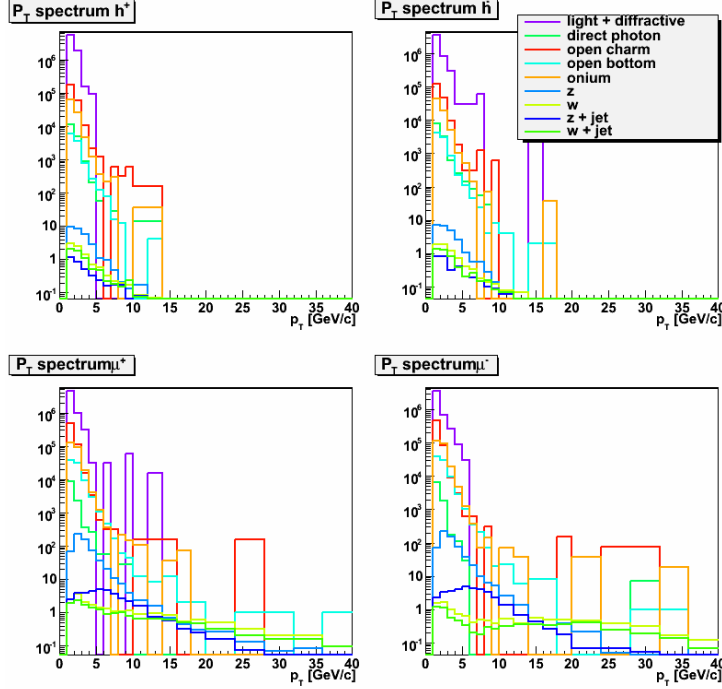


Figure 27: Scaled reconstructed hadron and muon yields as a function of the transverse momentum for the different sub-processes scaled to 0.1 pb^{-1} . While Z,W and similar processes contain already sufficient statistics, the statistics of the more abundant processes is still too low, therefore one does not see the fake high Pt muons from the light processes, yet.

This MC production will allow us to test all previously considered cuts to reduce the backgrounds in the high momentum Pt region for the $W \rightarrow \mu$ signals. In comparison to the previous, mostly single particle simulations, it will be possible to test these under realistic conditions and also be able to investigate further isolation criteria. Using Pythia, it will be possible to obtain a reliable estimate of the actual background level seen in Run9 and in simulations.

b. Offline Software (Richard Hollis, U. C. Riverside)

The offline software comprises a number of separate projects: to facilitate the detector readout, form particle trajectories from the detector hits, and simulate the detector response to particles and other effects. As such, the software development work is naturally divided into several sub-components, each with different timescales for completion.

The first subcomponent is the geometrical description of the detector. Here, once the detector is read out, the hit positions need to be translated into a usable real space format. The geometry is now fully described within the PHENIX software, with a unique identifier map between the readout electronics and the final geometrical description. The software code for the geometry is built with sufficient redundancy such that small

movements of the detector can be easily accounted for without major infrastructure changes in the software. Final modifications to this, due shortly, will implement the final numbering scheme into the station 1 description, which needs no further changes to the actual description. After full installation and first data-taking, it will be likely that the detector description will need attention to account for small variations in the construction of each module. Thus, alignment procedures will need to be coded to allow for the best possible description of our detector within the PHENIX software.

Small software advances have been made to aid the trajectory finding with the RPCs. An algorithm has been developed to find the nearest hit to a given trajectory. This algorithm is generic enough that it also can be applied to other parts of the RPC software. In the context of alignment, one could find tracks with the MuId and/or MuTr and then find the closest approach to the RPC hits. This can later be used to minimize the distance of closest approach on a global level, across the whole detector, and thus obtain the final alignment. In a more important application, once aligned, the closest hits could be attached to the full MuId/MuTr track ready for re-analysis for improved track reconstruction. For this software component, the next steps will involve clustering hits to form. This represents the occasions where more than one RPC strip is hit.

Work on the final subcomponent of the offline software has focused on basic detector readiness for the upcoming simulations. The first part of this requires a realistic description of the detector: the geometry (completed as discussed) and the detector response. As mentioned in the prior discussion, some detector hits are partnered by adjacent hits belonging to the same projectile. Basic software has been developed to incorporate multiple adjacent hits into the effective read-out of the detector within the simulation. As a corollary, the software also now accounts for multiple hits on overlapping radial segments of the same station. The final piece of realism in the description is the inclusion of noise hits. Noise hits, which are prevalent in all detector strips at some level, cause hits without a projectile pass through a strip. In this case, the random hits are added, currently with a uniform rate per strip. For future development, again after the first data-taking, a more realistic noise simulation will be implemented. This will not require any infrastructure changes, but will need to utilize a database of measured noise rates, which will be different for each strip.

The current work on the RPC software has focused on the development of basic infrastructure needed to perform more detailed tasks during data taking and simulation. Over the next few months, a long list of projects needs either completion (mostly after data-taking) or starting. The most important of these is the creation of a database table to handle the geometry (and geometry tables) in a consistent manner. This will also be able to hold other information such as the noise rate, classified dead or hot channels, and clustering probabilities.

c. Cosmic Ray Background Run-9

(Xiaochun He, Georgia State)

Based on the Run-9 cosmic run data, the extracted cosmic muon rate is 2.5 ± 0.1 mHz for the p_T range of 20 to 40 GeV/c. An analysis note has been drafted and can be found at:

<https://www.phenix.bnl.gov/WWW/p/draft/hexc/forward/cosmic2009/PHENIX2007CosmicRayRunAnalysis.pdf>.

The simulation study of the cosmic ray acceptance of the Muon Arms is still in progress. The results from this study will be very important for quantifying the momentum dependent cosmic ray background for the W measurement. Figure 28 below shows event displays from the PHENIX detector simulation package (called PISA) and a reconstructed cosmic ray track. This analysis requires a few important modifications to the existing muon reconstruction software in order to properly determine the track momentum and energy since the cosmic rays are traversing the Muon Arm detectors in the opposite direction as to those from the interaction region of the colliding beams.

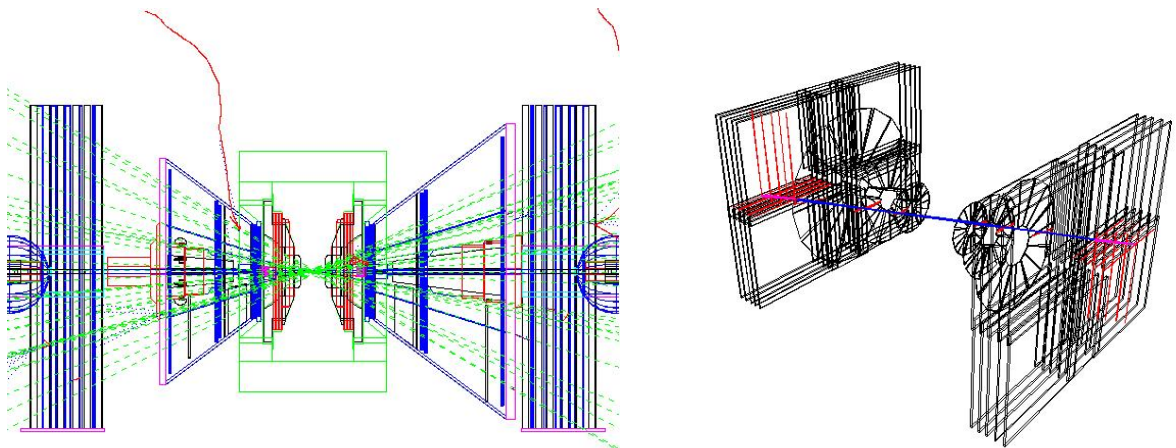


Figure 28: The right figure shows event displays from the PHENIX detector simulation package (called PISA) and a reconstructed cosmic ray track.

At the end of Run-9, several cosmic ray runs were taken with the RPC prototype D (RPC2 & RPC3) included. Jun Ying has been studying the matching between the reconstructed muon tracks from MuTr and MuID and their projected hits in these two RPC stations. So far the matching efficiency is less than 50%. It is believed that there are some hidden bugs in the matching code (either from the RPC strip geometry currently implemented in the reconstruction software or from the chamber misalignment). Jun Ying is still working on this analysis.

Projected progress for the coming months is in three areas. (1) To continue the cosmic ray tracking matching between the MuTr and RPC hits. The success of this analysis will

not only provide the RPC detector alignment with respect to the existing muon spectrometer but also allow us to do an RPC efficiency study in situ. (2) We will continue on the simulation studies for understanding the reconstruction efficiency of cosmic ray muons. The results will be summarized in an analysis note. (3) We would like to take more cosmic ray data at the beginning of Run-10. Xiaochun He will be the first Period Coordinator for Run-10 starting in mid December and will oversee this effort.

4. Monitoring of Long Term RPC Operation (Jun Ying, Georgia State)

In order to efficiently operate the PHENIX RPC detector in years to come, we have set up a test stand at Georgia State University (GSU) for monitoring RPC performance. This is a continuing RPC R&D effort by the PHENIX Forward Trigger group.

As shown in Figure 29, three RPC modules are included in the test stand. The top RPC module consists of two Korean oiled gas gaps, which are the same as those used in PHENIX. The middle RPC module consists of one Korean oiled gas gap and one non-oiled. The bottom RPC module consists of two gas gaps, which were made at GSU. Two scintillator paddles are used for a cosmic muon trigger. The scintillator paddles cover an area of two readout strips wide in each RPC module.



Figure 29: Test setup for long term RPC performance monitoring

As an example, Figure 30 shows the dark current variation of the top RPC module for the past nine months. The two gas gaps ran above 9300 volts for most of the time. We also recorded the humidity and temperature at the same time. Both gas gaps in the top RPC module showed good dark current performance over this period ($< 0.1 \mu\text{A}$).

From mid September of 2009, after the Forward Trigger quarterly meeting, a series of tests were performed to confirm the effect of gas poisoning if multiple RPC gas gaps were connected in a daisy-chain. Figure 3 shows dark current variation of the top RPC modules during these test periods. Before September 17, 2009, the gas flow was from top

to bottom. The dark current was very small ($<0.1 \mu\text{A}$) for both gas gaps during the nine-month monitoring period.

On September 17, 2009, the gas was changed to flow from the bottom module to the top. As seen from Figure 31, a fast rise of the dark current from the KrOilUp (blue line) gas gap was observed from this day onward. The trend of the rising dark current from this gas gap was immediately stopped once the gas flow was reversed back to the flowing direction as employed before September 17, 2009.

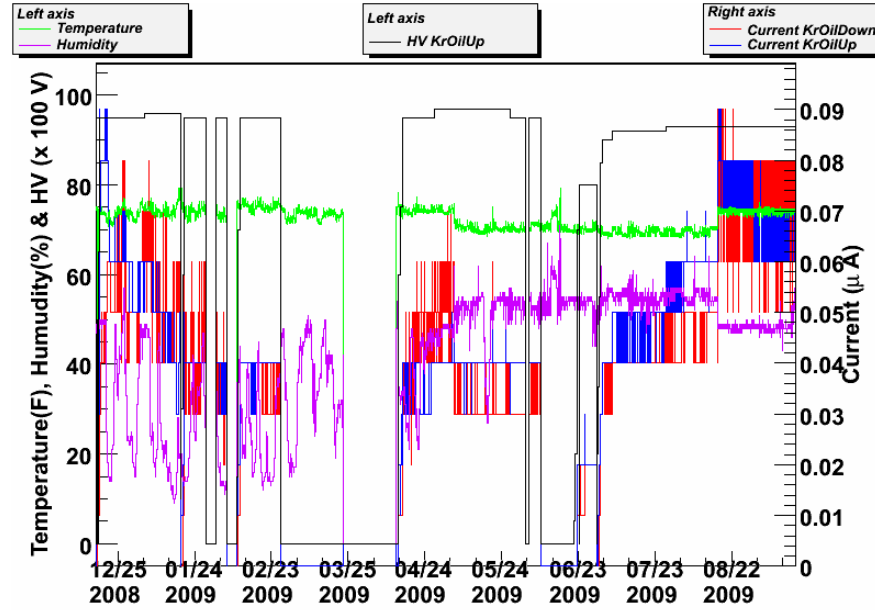


Figure 30: Dark current variation for the Top RPC during a nine-month monitoring.

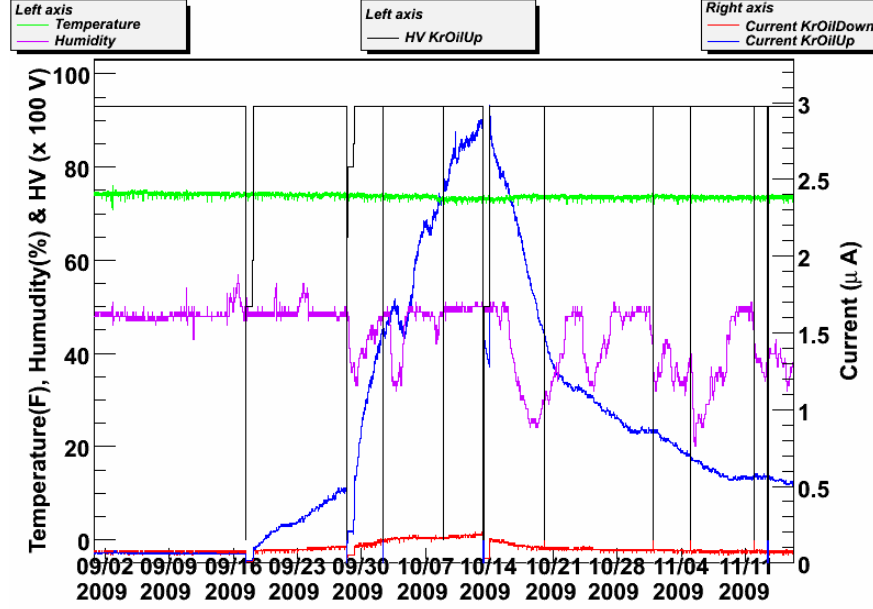


Figure 31: Dark current variations of the Top RPC before and after the gas flow direction were reversed.

We are currently working on a technical note to document the observations from these tests. In the mean time, we would like to continue the test with and without a SF_6 component in the RPC gas mixture.

5. Progress Polarization & Luminosity 500 GeV (Matthias Grosse Perdekamp, UIUC)

A first 5 week long run with polarized protons in RHIC at $p_{\text{beam}}=250$ GeV took place from March 5, 2009 to April 12, 2009. The average store luminosity was $L_{\text{average}}=5.5 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$, with a total delivered integrated luminosity to PHENIX of $\int L dt=15 \text{ pb}^{-1}$. The average beam polarization was $P_{\text{beam}}=0.35$ compared to $P_{\text{beam}}=0.55$ at a beam momentum of $p_{\text{beam}}=100$ GeV.

During the run proton-proton collisions at $\sqrt{s}=500$ GeV were quickly established. The beam backgrounds in the PHENIX muon spectrometers were carefully monitored. Backgrounds from beam losses were monitored through the dark currents in the muon identifier and the RPC prototype half octants that had been installed prior to run 9. In addition 8 scintillator counters were installed to monitor background rates from beam losses. The scintillator counters were located near the RPC-3 half octant prototype. It was found that the backgrounds from beam losses are well within the rates acceptable both for the RPCs as well as the present muon identifier.

Collision related backgrounds were studied with the existing PHENIX spectrometer. It was found that the background levels for the existing muon tracking detectors are significantly higher than in previous runs. It is presently being studied if it may be

necessary to adapt the existing shielding in the PHENIX muon spectrometers (previously optimized for $p_{\text{beam}}=100$ GeV) to the higher beam energy of 250 GeV. For the full size RPC-3 half octant prototype collisions related backgrounds were found to be modest.

The first operational experience with protons in RHIC at $p_{\text{beam}}=250$ GeV led to the finding that the betatron tune phase space between resonances leading to polarization loss and instabilities leading to luminosity loss is limited. A number of measures and upgrades are being implemented to gain the necessary tune stability and further to improve polarization and luminosity of RHIC for polarized protons at $p_{\text{beam}}=250$ GeV.

The RHIC upgrades planned to be in place for run 2011 are:

- AGS horizontal tune jump system.
- Improved orbit control in RHIC.
- 10 Hz orbit feedback.
- 9 MHz RF system.
- Spin flipper upgrade.

These upgrades lead to the following projections from CAD for Run-11:

- for $p_{\text{beam}}=100$ GeV: $\int L dt = 2 - 3 \text{ pb}^{-1} / \text{week}$, $P_{\text{beam}} = 50 - 65\%$.
- for $p_{\text{beam}}=250$ GeV: $\int L dt = 5 - 12 \text{ pb}^{-1} / \text{week}$, $P_{\text{beam}} = 35 - 50\%$.

The integrated luminosity per week specified above takes into account PHENIX efficiencies and acceptance as measured in the past run.

With additional RHIC upgrades, including a polarization and intensity upgrade of the polarized source and the electron lensing upgrade for RHIC, it is expected that the polarization in RHIC will reach 70% for run 14 and the weekly integrated luminosity recorded in PHENIX will reach $\int L dt = 20/\text{pb}/\text{week}$.

We expect that data taking at $\sqrt{s}=500$ GeV will resume in run 2011 and that PHENIX will acquire $\int L dt = 300/\text{pb}$ by the end of 2014 with an average beam polarization of $\langle P_{\text{beam}} \rangle = 0.6$. We anticipate that about 25-30 weeks of running distributed over 4 years are needed to achieve this target performance for W-physics with the PHENIX muon spectrometers.

6. Personnel for RPC Production

(John Hill, Iowa State)

The factory at BNL for the production and testing of the RPC detectors is managed by Young Jin Kim, a UIUC postdoc. In addition IhnJea Choi and Anselm Vossen, also UIUC postdocs spend a major part of their efforts in the RPC factory. Major work at the factory is carried out by the UIUC graduate students Cameron McKinney, Beau Meredith, Scott Wolin and Ruizhe Yang. In addition Dave Northacker, an expert on gas systems, will spend one to two weeks per month working in the factory.

Two senior graduate students from Korea, Byungil Kim and Kwangbok Lee, continue to spend 50% of their time working on RPC production. An new graduate student, Chong Kim from Korea University spends 100% of his time in the RPC factory. In addition two students from Hanyang University in Korea, Jeong Su Kang and Byeong Hyeon Park, spend 12 and 6 months, respectively, working in the RPC factory.

For the summer of 2009 a large number of undergraduate students from Abilene Christian University, Morgan State University and Muhlenberg College traveled to BNL to work on construction and testing of the RPC-3N chambers. The names of these students are given in section 1A3. The Abilene students are under the supervision of Prof. Rusty Towell. Prof. Towell's work is supported by the NSF-MRI and the DOE Medium Energy Program. The Morgan State students are under the supervision of Prof. William Powell. Prof. Powell is supported by FaST-NSF grant. The Muhlenberg students are under the supervision of Prof. Brett Fadem. Prof. Fadem is the recipient of a new NSF grant.

In addition two first year graduate students from Iowa State University worked on the RPC project. They are James Bowen and Joshua Perry, both under the supervision of Prof. John Lajoie. Several members of the Iowa State group work on the design and construction of the level-1 trigger. Their contributions are discussed in section A2c.

B. Budget Summary (Perdekamp, UIUC)

Item	budget 9-08	proj. cost 1-09	proj. cost 5-09	proj.cost 12-09	change in projected cost
FEE R&D	\$ 261,709	\$261,709.0	\$261,709.0	\$261,709.0	\$0.0
FEE	\$ 600,337	\$535,332.0	\$519,822.0	\$497,751.0	\$102,585.8
LL1	\$ 299,520	\$288,920.2	\$274,192.5	\$268,709.5	\$30,810.5
RPC Engineering	\$ 161,716	\$159,248.4	\$158,358.6	\$157,107.4	\$4,608.3
RPC R&D	\$ 117,562	\$143,862.0	\$143,862.0	\$143,862.0	(\$26,300.0)
RPC Production	\$ 707,116	\$610,606.9	\$576,841.2	\$601,591.2	\$105,524.8
Gas System	\$ 60,000	\$60,000.0	\$60,000.0	\$60,000.0	\$0.0
High Voltage	\$ 96,000	\$96,000.0	\$128,000.0	\$128,000.0	(\$32,000.0)
Total	\$ 2,303,959	\$2,155,678.5	\$2,122,785.3	\$2,118,730.1	\$185,229.4
contingency	\$ 183,372	\$255,611.4	\$243,611.4	\$83,589.4	
committed	\$1,086,468	\$1,403,364.8	\$1,673,896.0	\$1,864,370.1	
fraction committed					
	47%	61%	73%	88%	

We use as reference the budget presented at the BNL review of the PHENIX muon trigger upgrade from September 2008. This budget reflects the muon trigger configuration with two RPC stations. The "projected cost" is updated from the reference budget using improved cost estimates based on orders submitted and bids received. Changes in projected cost also arise from unspent contingency. The amount of funds committed has increased to about \$1.86 million or 88% of the total projected cost. The

cost to completion is \$254.4k. The uncommitted contingency is currently \$83.6k or about 30% of the cost to completion.

Spending has been completed on the following sub-projects:

- (1) RPC-3 gas gaps, signal planes, detector boxes, half octants
- (2) LL1 trigger processors and testing
- (3) FEE R&D
- (4) Preamplifier-discriminator board production and testing
- (5) TDC production and testing
- (6) RPC-1 gas gaps

The major outstanding purchases include the RPC-1 signal planes, RPC-1 detector boxes, the FEE trigger boards and the gas system.

We note that we have closed successfully the project dependencies on the CMS vendors for bakelite and preamplifier-discriminator chips in Italy and for gas gaps in Korea. The only remaining dependence on CMS vendors is associated with the vendor for signal planes and detector boxes for RPC-1 in Beijing.

Significant commitments since the last report include (1) orders of parts for the front end electronics: \$32k (2) order of RPC-1 gas gaps for about \$51k. The cost for the RPC-1 gas gaps was significantly higher than projected, \$51k instead of \$23k.

The original budget of \$2.3 million included \$100k of voluntary matching contributions each from UCR and UIUC. These funds were included in the overall contingency reported earlier. However, the UCR matching contribution was designated for the support of a postdoc to be hired for the project and should not have been included in the equipment budget. The hire now has occurred and the contingency has been corrected and reduced by \$100k. At UIUC about \$50k of the matching contribution were spent on graduate student support before the scheduled account closeout. The contingency has been reduced by this amount.

C. Schedule Summary (Perdekamp, UIUC)

- (1) Electronics: We believe that the schedule for trigger processors and front end electronics is not on the critical path and that all electronics will become available as needed for the detector assembly and integration (bold face indicates tasks completed):

- (a) Front end electronics: (completion date: 6-30-2010)

Amplifier-discriminator cards: complete for RPC 1 and 3:	09-30-2009
TDCs for RPC-3 north completed:	12-07-2009

TDCs for RPC-3 south and RPC-1:	03-31-2010
Trigger card: communication test with LL1:	01-31-2010
Trigger card: production:	06-30-2010

(b) Trigger processors (LL1): (completion date: 7-31-2010)

Base board and tile board assembly and testing completed:	11-01-2009
LL1 system integrations for north muon arm during run 10:	06-30-2010
LL1 system integration for south muon arm:	07-31-2010

(2) RPC production and integration: It was desirable for PHENIX to split the RPC-3 installation into two steps and to carry out the north installation in the shutdown of 2009 and the south installation in the shutdown 2010. The main advantage of a staged integration is the ability to better balance efforts for different detector upgrades within the PHENIX technical support group. In the reporting period we meet a very aggressive schedule to successfully assemble, test and install all RPC-3 half octants.

(a) Gas gap production at KODEL (Korea University):

RPC-3 gaps completed:	06-11-2009
RPC-1 gaps completed:	09-30-2009

(b) Gas gap Q&A:

RPC-3 north	07-31-2009
RPC-3 south	01-31-2010
RPC-1	05-31-2010

(c) Detector module assembly:

RPC-3 north	08-31-2009
RPC-3 south	02-28-2010
RPC-1 octant assembly	06-30-2010

(d) Half octant assembly:

RPC-3 north	10-20-2009
RPC-3 south	04-30-2010

(e) Half octant or octant burn in tests:

RPC-3 north	11-07-2009
RPC-3 south	05-30-2010
RPC-1	07-31-2010

(f) Installation:

RPC-3 north	11-10-2009
RPC-3 south ready for installation	06-01-2010
RPC-1 ready for installation	08-01-2010

D. Talks

Below we give a list of 67 talks and poster presentations given since the beginning of our NSF-MRI grant on 9-1-05. Note that 28 of these presentations were given by undergraduate students studying at Abilene Christian University and Muhlenberg College in the undergraduate sessions at the DNP meeting

- 1) John Lajoie, "The PHENIX Forward Upgrade," PANIC05, Santa Fe, New Mexico (October 2005)
- 2) Rusty Towell, "Measuring the Spin of the Proton with an Upgraded PHENIX Muon Trigger," Texas Section APS/AAPT/SPS, San Angelo, TX (March 2006)
- 3) Rusty Towell, "Research at National Accelerator Laboratories Involving ACU Undergraduate Students," CAARI 2006, Fort Worth, TX (August 2006)
- 4) Rusty Towell, "Physics Capabilities of the PHENIX Muon Trigger Upgrade," Texas Section of the APS, Arlington, TX (October 2006)
- 5) Daniel Jumper, "Integration constraints on a future high Pt muon trigger for PHENIX at RHIC," Joint meeting of Texas Sections of APS/AAPT, Arlington, TX, (October 2006)
- 6) Austin Basye, "RPC Detector Research and Development for PHENIX," Joint meeting of Texas Sections of APS/AAPT, Arlington, TX, (October 2006)
- 7) Ryan Wright, "Resistive Plate Chamber Test Stand and Read Out System for the PHENIX RPC Forward Upgrade," Joint meeting of Texas Sections of APS/AAPT, Arlington, TX, (October 2006)
- 8) John Wood, "Data Acquisition in Research and Development of Resistive Plate Chambers for the Trigger Upgrade for the PHENIX experiment at RHIC," Joint meeting of Texas Sections of APS/AAPT, Arlington, TX, (October 2006)
- 9) John Lajoie, "PHENIX Muon Trigger Upgrade," SPIN 2006, Kyoto, Japan, (October 2006)
- 10) Rusty Towell, "Muon Tracking at PHENIX and FNAL Experiments," Workshop on Muon Detection in the CBM Experiment, GSI Darmstadt, Germany, (October 2006)
- 11) Austin Basye, "RPC Detector Research and Development for PHENIX," Division of Nuclear Physics Meeting of the APS, Nashville, TN, (October 2006)
- 12) Daniel Jumper, "Integration constraints on a future high Pt muon trigger for PHENIX at RHIC," Division of Nuclear Physics Meeting of the APS, Nashville, TN, (October 2006)
- 13) Jun Ying, "RPC Prototypes for the PHENIX Forward Muon Trigger Upgrade at RHIC," Division of Nuclear Physics Meeting of the APS, Nashville, TN, (October 2006)
- 14) Nathan Sparks, "The Results of a Resistive Plate Chamber Study for the PHENIX Forward Muon Trigger Upgrade," Division of Nuclear Physics Meeting of the APS, Nashville, TN, (October 2006)
- 15) John Wood, "Data Acquisition in Research and Development of Resistive Plate Chambers for the Trigger Upgrade for the PHENIX experiment at RHIC," Division of Nuclear Physics Meeting of the APS, Nashville, TN, (October 2006)

- 16) Ryan Wright, "Resistive Plate Chamber Test Stand and Read Out System for the PHENIX RPC Forward Upgrade," Division of Nuclear Physics Meeting of the APS, Nashville, TN, (October 2006)
- 17) Xiaochun He, "PHENIX Forward Muon Trigger Upgrade at RHIC," poster at QM2006, Shanghai, China, (November 2006)
- 18) Donald Isenhower, "Resistive Plate Chambers and the Forward PHENIX Upgrade at RHIC," Joint Spring Meeting of the Texas Sections of APS, AAPT and SPS, Abilene, TX, (March 2007)
- 19) John Lajoie, "Studying Proton Spin Structure with the PHENIX Upgrade Program," DIS2007, Munich, Germany, (March 2007)
- 20) Ralf Seidl, Invited talk at the Parity violating spin asymmetries workshop, BNL, Upton, NY, (April 2007)
- 21) Matthias Grosse Perdekamp, "Spin Physics Overview," PHENIX Forward Upgrade Workshop, Santa Fe, NM, (May 2007)
- 22) Matthias Grosse Perdekamp, "Spin Physics with PHENIX Detector Upgrades," AGS&RHIC User Meeting, BNL, Upton, NY (June 2007)
- 23) Austin Basye, "Muon Spectrometer Upgrades at PHENIX," Invited talk at the International Conference for Physics Students, London, England, (August 2007)
- 24) Beau Meredith, "A Cosmic Ray Test Stand for the PHENIX Muon Trigger RPCs," APS Fall Meeting, Newport News, Virginia (October 2007)
- 25) Young Jin Kim, "Design and R&D for the PHENIX Muon Trigger RPCs," APS Fall Meeting, Newport News, Virginia (October 2007)
- 26) Dillon Thomas, "Quality Analysis and Control Procedures for the PHENIX RPC Forward Trigger Upgrade," Division of Nuclear Physics Meeting of the APS, Newport News, VA, (October 2007)
- 27) Ryan Wright, "Bakelite Surface Resistivity Measurements for Muon Trigger RPCs in PHENIX," Division of Nuclear Physics Meeting of the APS, Newport News, VA, (October 2007)
- 28) Brett Fadem, "Physics with the PHENIX Muon Trigger Upgrade," Division of Nuclear Physics Meeting of the APS, Newport News, VA, (October 2007)
- 29) Amanda Caringi, "Testing Scintillator Efficiency for Use in RPC Test Stand for PHENIX at RHIC," Division of Nuclear Physics Meeting of the APS, Newport News, VA, (October 2007)
- 30) Justine Ide, "Database Design and Data Retrieval for the PHENIX RPC Factory," Division of Nuclear Physics Meeting of the APS, Newport News, VA, (October 2007)
- 31) Rusty Towell, "The Fast Resistive Plate Chamber Based Muon Trigger Upgrade for PHENIX," IEEE Nuclear Science Symposium, Honolulu, Hawaii, (October 2007)
- 32) Young Jin Kim, "The PHENIX Fast Muon Trigger Upgrade Project (poster)," Quark Matter 2008, Jaipur, India (February 2008)
- 33) Beau Meredith, "PHENIX RPC R&D for the fast RPC muon trigger upgrade," NIM 602, 3, Pages 766-770, Proceedings of the IX International Workshop on Resistive Plate Chambers and Related Detectors, 2008 Tata Institute of Fundamental Research, Mumbai, India, (February 2008)

- 34) Byungsik Hong, "RPC production for fast muon trigger system for PHENIX," NIM 602, 3, 1 May 2009, Pages 644-648, Proceedings of the IX International Workshop on Resistive Plate Chambers and Related Detectors, Tata Institute of Fundamental Research, Mumbai, India, (February 2008)
- 35) Rusty Towell, "Assembly, testing, and installation of the fast RPC muon trigger upgrade for PHENIX," NIM 602,3, 1 May 2009, Pages 705-708, Proceedings of the IX International Workshop on Resistive Plate Chambers and Related Detectors, Tata Institute of Fundamental Research, Mumbai, India, (February 2008)
- 36) Daniel Jumper, "Calibrating Scintillator position measurement for testing RPC modules for PHENIX at RHIC," Spring Meeting of the Texas Sections of APS, Corpus Christi, TX, (March 2008)
- 37) Dillon Thomas, "Quality Analysis and Control Procedures for the PHENIX RPC Forward Trigger Upgrade," Spring Meeting of the Texas Sections of APS, Corpus Christi, TX, (March 2008)
- 38) John Hill, "Use of Resistive Plate Chambers in the Upgrade of the PHENIX Forward Spectrometers," CAARI-2008, Fort Worth, Texas (August 2008)
- 39) Xiaochun He, "PHENIX Detector Upgrade for Triggering Fast Muons from W-Boson Decays Using RPC Technology," The 18th International Symposium on Spin Physics, Charlottesville, VA, (October 2008)
- 40) Ralf Seidl, Invited spin overview talk, Division of Nuclear Physics Meeting of the APS, Oakland, CA, (October 2008)
- 41) Austin Basye, "Forward RPC Trigger Design and Integration at PHENIX," Division of Nuclear Physics Meeting of the APS, Oakland, CA, (October 2008)
- 42) Timothy Jones, "PHENIX RPC Production Database," Division of Nuclear Physics Meeting of the APS, Oakland, CA, (October 2008)
- 43) Joseph Kish, "A Systematic Study of RPC Spacer Bond Strength for PHENIX," Division of Nuclear Physics Meeting of the APS, Oakland, CA, (October 2008)
- 44) Dillon Thomas, "Quality Control for the RPC Upgrade for PHENIX," Division of Nuclear Physics Meeting of the APS, Oakland, CA, (October 2008)
- 45) Caitlin Harper, "Event Display for the RPC Test Stand at PHENIX," Division of Nuclear Physics Meeting of the APS, Oakland, CA, (October 2008)
- 46) Thalassa Sodre, "Assembling Nine Resistive Plate Chamber Prototype Modules for PHENIX," Division of Nuclear Physics Meeting of the APS, Oakland, CA, (October 2008)
- 47) David Broxmeyer, "Assembly and Quality Assurance Tests of Gas Gaps for the PHENIX Muon Trigger Upgrade," Division of Nuclear Physics Meeting of the APS, Oakland, CA, (October 2008)
- 48) Phil Bailey, "The High Voltage System for the PHENIX RPC Test Stand," 2008 Quadrennial Congress of Sigma Pi Sigma, Fermilab, (November 2008)
- 49) Dillon Thomas, "Quality Control for the RPC Upgrade for PHENIX," 2008 Quadrennial Congress of Sigma Pi Sigma, Fermilab, (November 2008)
- 50) Timothy Jones, "PHENIX RPC Production Database," 2008 Quadrennial Congress of Sigma Pi Sigma, Fermilab, (November 2008)
- 51) Ralf Seidl, Invited PHENIX talk at the GHP workshop, Denver, CO, (April 2009)

- 52) Rusty Towell, "Assembly and Testing of the RPC Upgrade for the PHENIX Muon Arms," 3rd Joint Meeting of the APS Division of Nuclear Physics and the Physical Society of Japan. Waikoloa, Hawaii, (October 2009)
- 53) Rusty Towell, "Improving the PHENIX Muon Trigger using Resistive Plate Chambers," IEEE Nuclear Science Symposium, Orlando, FL, (October 2009)
- 54) Brett Fadern, "Performance of PHENIX Prototype Resistive Plate Chambers," 3rd Joint Meeting of the APS Division of Nuclear Physics and the Physical Society of Japan, Wailoloa, Hawaii, (October 2009)
- 55) David Broxmeyer, "The Muon Tracker Front End Electronics for the PHENIX Muon Trigger Upgrade," 3rd Joint Meeting of the APS Division of Nuclear Physics and the Physical Society of Japan, Wailoloa, Hawaii, (October 2009)
- 56) Caitlin Harper, "Chamber Performance of Prototype Resistive Plate Chambers for the PHENIX Forward Trigger Upgrade," 3rd Joint Meeting of the APS Division of Nuclear Physics and the Physical Society of Japan, Wailoloa, Hawaii, (October 2009)
- 57) John Hill, "Upgrade of the PHENIX Forward Muon Spectrometers for Spin Physics at RHIC," Prairie Section APS, Iowa City, Iowa (November 2009)
- 58) Matthias Grosse Perdekamp, " RHIC Spin: Next Decade," invited talk RHIC Spin Collaboration Meeting, Berkeley, CA, (November 2009)
- 59) Ralf Seidl, "PHENIX W Prospects," invited talk RHIC Spin Collaboration Meeting on: "RHIC Spin: Next Decade," Berkeley, CA, (November 2009)
- 60) Itaru Nakagawa, "Muon Trigger Upgrade for W Physics," Winter Workshop Nuclear Dynamics-2010, Ocho Rios, Jamaica (January 2010)
- 61) Young Jin Kim, "RPC Based Muon Trigger Upgrade for the PHENIX Experiment at RHIC," RPC 2010 Workshop, Darmstadt, Germany (February 2010)
- 62) Rusty Towell, "Quality Control of RPCs for the PHENIX Trigger Upgrade," RPC 2010 Workshop, Darmstadt, Germany (February 2010)
- 63) Sung Park, RPC Gap Talk, RPC 2010 Workshop, Darmstadt, Germany (February 2010)
- 64) Xiaochun He, "Long-term RPC Performance Monitoring," RPC-2010 X Workshop on Resistive Plate Chambers and Related Detector at GSU, Darmstadt, Germany, (February 2010)
- 65) IhnJea Choi, "Status of the Muon Trigger Resistive Plate Chamber Upgrade Project in PHENIX," APS April Meeting, Washington, DC (February 2010)
- 66) Murad Sarsour, "Performance of PHENIX Resistive Plate Chambers," APS April Meeting, Washington, DC (February 2010)
- 67) John Hill, "Measurement of the Proton Quark Structure from Parity Violating Lepton Asymmetries in W Production in PHENIX at RHIC," APS April Meeting, Washington, DC (February 2010)